HANDBOOK ON DIE CASTINGS

PRECISION CAST

Giving complete information about dies and casting processes, metals, methods of fabrication, finishing etc—with useful tables.

PRECISION CAST

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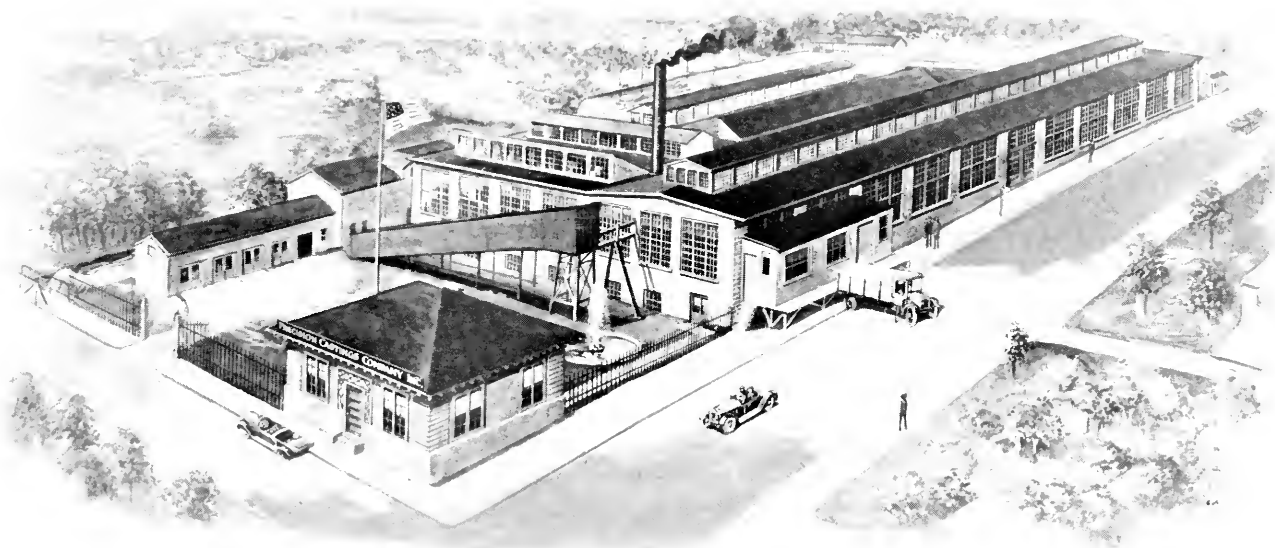

Precision Castings Company, Fayetteville Plant.

HAND-BOOK

ON

DIE-CASTINGS

CONTAINING

USEFUL INFORMATION FOR
MANUFACTURERS AND
ENGINEERS

CONCERNING

METALS, DESIGN, PROCESSES,
METHODS OF FINISHING,
FABRICATING, ETC.,
WITH TABLES

By

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Published by

PRECISION CASTINGS CO., INC.

SYRACUSE, N. Y.

FACTORIES:

FAYETTEVILLE, N. Y. AND PONTIAC, MICH.

Roaring forge and reddening glow,
Rhythmic swing of hammer blow,
May thy heartbeats never more
Pulsate to the songs of war.

Glorious deeds of mighty men
Turn your strength to peace again.
Muscle and brawn and gallantry now
Turn to the factory, turn to the plow.

From sea to sea, throughout the land,
From northmost lakes to the Rio Grande,
Assemble your hosts and gather your might
Just as you did when you fought for your right.

Up and to work! Lead the crusade,
Masters of markets, princes of trade;
Carry Old Glory to the ports of the World—
Fairly and justly and proudly unfurled.

Introduction

The publication of this book is prompted by a desire to give users of die-castings and those interested in the art, complete information on the subject of die-castings and relative topics, as there is little available literature on the subject.

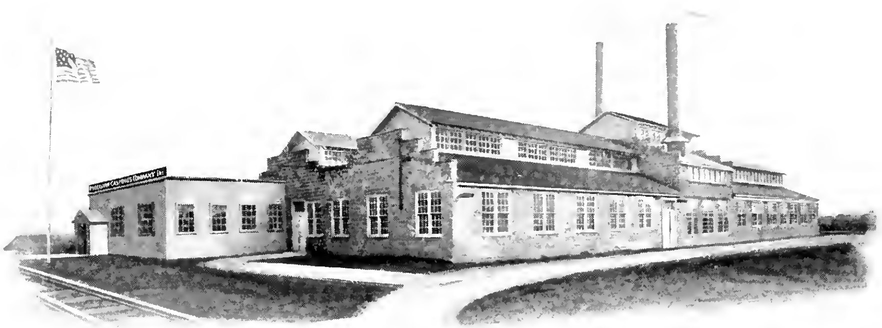
We hope that the information herein given will bring about better co-operation and understanding between users and producers, and will enable users to take greater advantage of the many economies and improvements in product and production made possible by the die-casting process.

The present development and wide use of die-castings is not to be credited to any one man or organization. It is the result of contributions to the art made by many men and many organizations almost all of whom, it may be noted, did their work in the United States. Die-casting is today essentially an American industry.

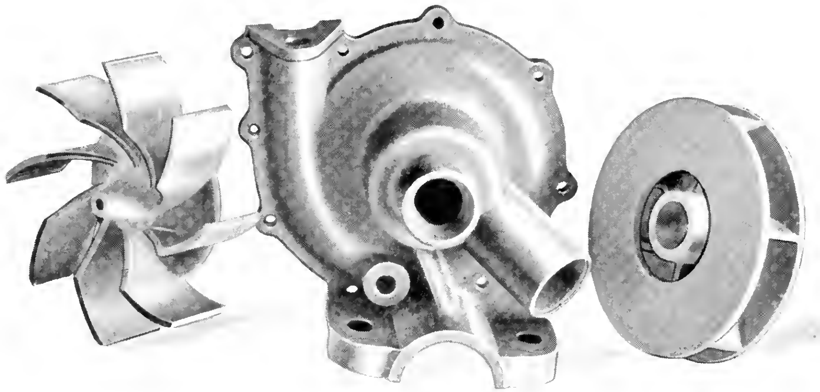
Die-casting machines for making type, which were the forerunners of the modern die-casting machines, were built in this country over seventy years ago. The modern industry is about thirty years old and came with the advent of quantity production of mechanical devices and machines.

The Precision Castings Co., Inc., whose work is herein described, was organized in 1916 to take over the E. B. VanWagner Mfg. Co., organized in 1907, and the Precision Die Castings Co., organized in 1910. These companies have for years been widely and favorably known for the high character of their product and service. The combination has produced an organization doing an unusually wide range of work in large volume without departing in any respect from the highest and most exacting standards.

During the war our entire facilities have been devoted to government work, with few exceptions. We have made over one hundred different parts for motors,



Precision Castings Co., Pontiac Plant.



Water pump impeller, aluminum. *Combustion motor water pump, zinc alloy.* *Water pump impeller, tin alloy.*

bombs, shells, grenades, aeroplanes, trench mortars, guns, etc., in large quantities. Of one part for hand grenades alone, we delivered over 25,000,000 in less than ten months.

To be a die-casting, the part must be cast from fluid metal forced under pressure other than gravity into a metallic mold, sufficiently below the temperature of the fluid metal to chill it. Parts poured in non-metallic molds, or poured in metallic dies by gravity only, or formed up in dies under pressure from a plastic or semi-fluid state, are not properly referred to as die-castings and lack the accuracy and range of design made possible by the die-casting process. So far, the only metals successfully die-cast on a commercial scale are the alloys of zinc, tin, lead and aluminum fusing below about 1300° F. Brass and bronze die-castings have been offered to the trade at various times by several concerns, some of which have discontinued business because they were unable to apply their process to general commercial requirements, and others have been able to produce only a few simple parts in limited quantities. It is not so difficult to die-cast a few samples, but production on a commercial scale is a different matter. The reasons for this will become apparent in the following pages.

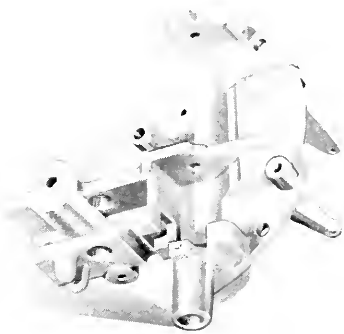
The inherent limitations of the die-casting process in its present development are such that only certain adaptable metals may be used, and when the particular strength and qualities of steels and bronzes are required, die-castings cannot be substituted for parts made of those metals.

The process is more accurate than punching or drawing sheet metals, because there is not the same wear on the dies, nor is the spring and distortion of drawn metal a factor. Forgings or parts pressed from plastic metal are not as accurate as die-castings, and cannot be produced in as wide a range of design.

The following list, showing some of the parts and devices for which die-castings are used, will give an idea of the extent to which the process has been applied in modern production.

Adding Machines
Automatic Controlling Devices
Automobile Accessories and Parts
Armature Parts
Ammeter Housings and Plates
Automatic Devices (small)
Ammunition
Air Pumps
Atomizers
Aeroplane Parts
Bearings (plain)
Brush Holders for Electric Motors
Brackets of various kinds
Cameras
Cash Registers
Carburetors
Cigarette Machines
Clocks
Check Protectors
Counting Machines
Cup Dispensers
Dental Appliances
Door Checks
Disinfecting and Sanitary Devices
Electric Horns and Signals
Envelope Machines
Engine Governors
Fire Extinguishers
Fare Boxes and Registers
Gears (small)
Gas Engines
Hinges
Hardware
Instruments of various kinds
Knobs and Handles
Lamps of various kinds
Loose Leaf Book Binding Parts
Magnetos
Moving Picture Machines
Motor Housings (small electric)
Marking Machines
Motorcycles
Meters of all kinds
Military Equipment and Devices
Milking Machine Parts
Numbering Machines
Novelties
Office Appliances
Organs
Optical Appliances
Pencil Sharpeners
Phonographs
Pianos
Piano Players
Prepayment Devices
Printing Presses and Machines
Pulleys
Plumbing Fixtures and Supplies
Rubber Molds
Switches (electric)
Switch Keys
Safety Razors
Starting, Lighting and Ignition Systems for Combustion Motors
Sealing Machines
Speedometers
Stamp Affixers
Storage Batteries
Soap Dispensers
Soda Fountain Fittings, Pumps, Etc.
Telephone Apparatus
Time Clocks
Typewriters
Tabulating Machines
Table and Kitchen Ware
Thermostatic Devices
Tractor Accessories and Parts
Vacuum Cleaners
Vending Machines
Vibrators and Massage Devices
Weighing Scales
Water and Oil Pumps

Speedometer frame—tin alloy. Dimensions held to .001". Note how the design reduces assembling to a minimum.



Vending machine,
zinc alloy.

I. Advantages of Using Die-Castings

There are numerous advantages in the use of die-castings, many of which are not fully appreciated until the castings are used for a given period and comparative data is available. In many cases they present manufacturing advantages peculiar to the job in hand, which it is not possible to point out in a general summary. Much depends on the character of the *workmanship*, *material* and *service* furnished.

Die-castings which do not measure up to high commercial standards in these three particulars frequently cause troubles and delays which destroy the very advantages which the process so admirably has over most others. It cannot be too strongly emphasized that comparative prices of die-castings offered from competing sources should not be decisive in the placing of orders, although it by no means follows that the lowest bidder offers the poorest material. On the contrary it frequently happens that the best die-castings are furnished by the lowest bidder because of his greater skill and experience which enable him to employ methods lower in cost and yet more thorough and effective in their results.

Accuracy and Inter-Changeability

The degree and range of accuracy which may be held is covered fully in a separate chapter under that heading (p. 51). It may be said here, that the elimination of error by avoiding the "human variable" is accomplished in die-castings to a greater extent than by any other process. The die is virtually a gauge and the size of the castings is in no way dependent upon the will or discretion of the operator. Consequently die-castings are interchangeable, which offers well understood advantages in manufacture and assembly and in making replacements for broken or worn parts.

Finish and Appearance

A die-casting, unlike a sand casting, has a perfect finish over its entire surface, which is smooth and clean-cut. The excellence of the finish is largely dependent upon the process used in manufacture, and upon the care and attention given the work. The highly developed and improved machines used by us make possible a standard which has never been attained by other methods.

Die-castings have a solid, substantial appearance, which makes them more suitable for high class machines and devices than sheet metal parts, which have, in many cases, a cheap or "tin can" appearance.

Almost any shape may be cast, frequently permitting a certain beauty or grace in outline which would be impractical or prohibitive in cost by other manufacturing methods.

Range of Design

A wider range of design is brought within practical and commercial limits by the die-casting process, than by any other single means. Many devices are now designed so that they may be made of die-castings, in whole or in part, and could not be commercially produced

by any other method. A great many devices which could not be produced before the advent of die-castings, have been resurrected and marketed by means of the process.

It is not possible to convey by any general statements the range of shapes and designs which may be die-cast, as the range of possible design is almost without limit. Each case, if it presents any difficulty, must be passed on by an experienced die-casting engineer to determine whether or not the design is practical. If the question is answered in the negative our engineers, when possible, always suggest changes which, if usable, will overcome the difficulties presented.

With exceptions, the practical limit in weight is about 10 pounds in the zinc and tin alloys, about 15 pounds in the lead alloys, and about 3 pounds in aluminum alloys. The size seldom exceeds 24″ over all.

Reduction of Assembling

It frequently happens that two or more parts which must be produced separately and assembled by other processes, may be combined in a single die-casting. The result is greater accuracy, lower cost, better appearance, and generally greater rigidity and strength, with no opportunity for the separate parts to get out of line or adjustment.

When assembling cannot be avoided for individual pieces, the parts may be so designed that the work of assembling is much simplified. This is done by making the parts lock into each other in such a manner that they cannot lose their adjustment and can readily be located in the proper position; for this purpose dowel pins on one part and corresponding holes in the other, or keys and keyways, tongued grooves, square holes, inter-locking lugs, etc., may be cast. Of course, the uniformity and accuracy of die-castings alone make assembling easy and inexpensive. We have been advised frequently by customers that the accuracy and finish of "Precision" castings has made possible a reduction in their piecework rates, as well as permitting other economies necessarily incident to higher and more dependable production.

Quick Delivery

Die-castings as a general rule cannot be made faster than plain punchings or simple screw machine parts, but they are less liable to delays in production caused by lack of sheet metal of suitable kind or the needed sizes or shapes of rods or bars used on the screw machines. But die-castings can always be produced much faster than similar parts can be sand cast and machined. Precision machines are capable of exceedingly high production. On long runs an average of over 300 operations of the dies per hour has been registered.

As a rule less labor is required to produce a die-casting than any other processes would require for the same part; consequently production is quicker and surer, because the die is virtually a positive automatic machine not subject to the errors of machine work.

We have not yet met with a case in which our daily production was below

the daily capacity of our customer to use the parts, excepting of course Government orders placed during the war.

When dies are once made, deliveries, when needed, may usually commence in a few days after receipt of order, dependent upon the amount of work involved in removing the gates and fins from the castings.

Cost

All things considered, a die-casting, when suitable, usually presents a cost advantage, but they are not always used for that reason alone. Intricate parts requiring a great deal of machining and finishing usually present a large saving. The die-casting process, generally speaking, is more expensive than sand casting, and for that reason sand castings that may be used without machining or finishing operations cannot be die-cast to advantage.

No idea of the cost of particular parts can be given, as this depends on the weight, design, and quantity ordered, as well as on the die equipment; quotations should be secured in each case.

In considering the cost of dies it must not be forgotten that they offset the investment usually needed in other processes for patterns, jigs, fixtures and special tools. Furthermore, dies are not subject to the wear and deterioration of other tools, as they are kept by us in perfect condition without charge.

Machining Advantages

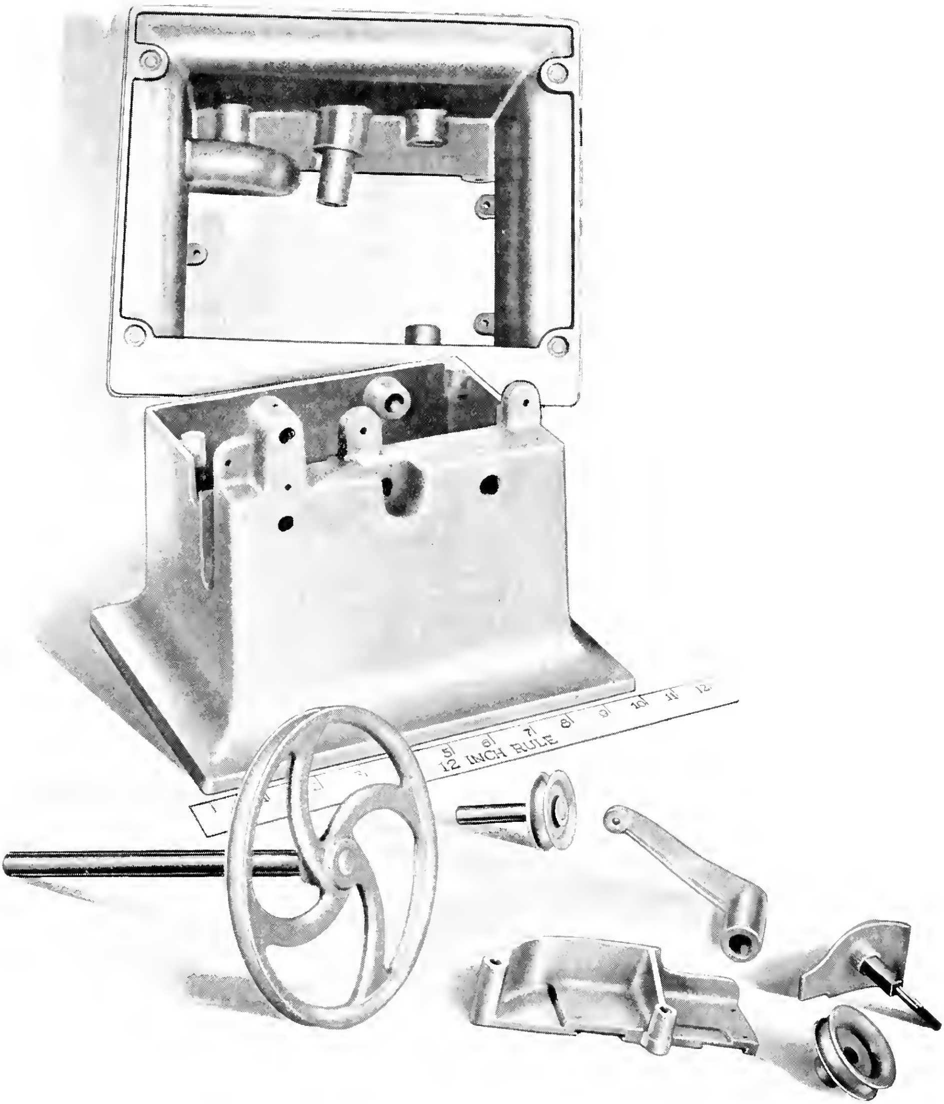
It is frequently advisable to do machine work on die-castings when the machining operations are inexpensive and the work of die-casting is thereby made simpler and less expensive. This is true of inside threads in most cases, and sometimes of inside grooves, under-cut slots, etc. When machine work is done it is simpler and cheaper than the same work done on sand castings, due to the uniformity of the die-castings, and the ease with which they may be located in jigs and fixtures. When holes are to be reamed or surfaces ground or machined less stock need be allowed and a lighter cut taken, due to the accuracy of the castings.

Manufacturing Advantages

All the manufacturing advantages cannot be enumerated because many are subject to the facilities of the manufacturer using them, and depend on the particular or peculiar problems involved in each case.

A user of die-castings reduces and frequently eliminates labor troubles, he avoids idle tool equipment, as is the case when the work required of certain tools is not up to their yearly capacity. To the same extent he has no depreciation or loss on equipment. He requires less capital for plant, he uses less factory space, less light, less power, or releases them for other purposes.

There are many hidden leaks and undiscovered losses in the average factory which run for long periods, resulting in some uncertainty as to what the actual cost of the work is. Die-castings, on the other hand, enable a manufacturer to secure his finished part ready for assembly at a definite, fixed, and dependable cost.



Envelope sealing machine,
Zinc and lead alloys.

II. Cost and Suggestions to Purchasers

Die-castings are sold at a price per piece or set of pieces, and the dies are the subject of a separate charge. The following factors of cost are considered in preparing estimates:

1. Weight.
2. Kind of metal used.
3. Quantity ordered in one run or setting of the dies.
4. Total quantity ordered.
5. Casting production per hour.
6. Cleaning operations required.

Die-castings, as pointed out before, are not always cheaper than the same parts produced by other processes, as the production of casting machines is not high compared with screw machines or presses. A casting machine to be run efficiently, requires two operators and represents a high daily maintenance cost for power, fuel and metal losses. It is therefore principally the labor cost of non-automatic manufacturing operations that is reduced by the use of die-castings, such as machine work of any kind, engraving, filing, fitting, grinding, spinning, bending, soldering, assembling, etc.

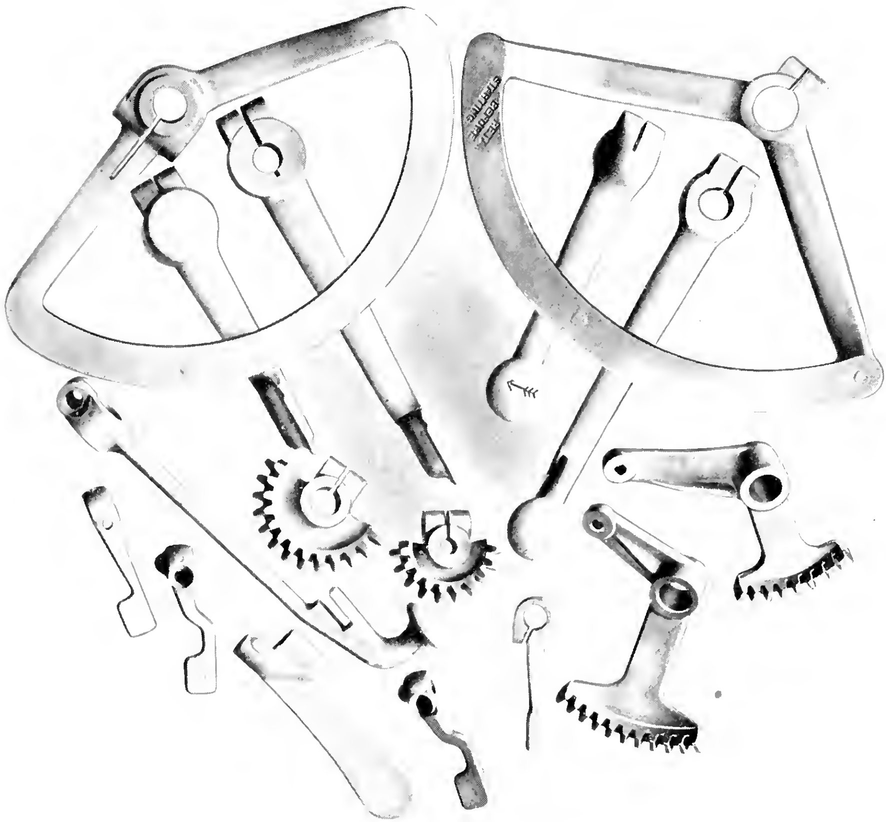
Setting the dies and getting them started is slow and troublesome work. After the dies are started it takes some time before the men are familiar with them and get up to a high average production. New dies require a certain time to be broken in and "seasoned". For these reasons, the process is essentially a quantity proposition, permitting very low production cost in long runs; but on the other hand in small quantities the cost is sometimes much greater than for the same production by other processes. Generally a thousand is the minimum lot, but very heavy and expensive parts are sometimes made to advantage in smaller quantities. Small and simple parts should be ordered in larger lots.

The white metals used for die-casting are all more expensive than steel or iron and in consequence when a part may be made of these metals at small labor cost, the expense will be less than that of die-castings.

Cleaning or trimming die-castings after they are made is an important item of cost. The gates must be removed and also the fins which appear around the parting line of the die, in holes and around the parting line of all moving parts in the die. This work is sometimes difficult and tedious and if carelessly or cheaply done will detract from the appearance and accuracy of the castings or spoil them entirely.

In large quantities, special jigs and fixtures or cleaning tools can be made to reduce this cost, but it nevertheless frequently amounts to more than the casting labor. In the Precision shops special attention is given to this branch of the work. We give each operation close inspection. We do not employ cheap labor for operations which require care or skill. The equipment used in our cleaning department is modern and accurate, many tools having been specially designed and built by us for work to which standard equipment is not so well adapted.

Comparatively light and simple parts, when used in quantities large enough to justify the die cost, may be made in multiple dies running as high as fifty im-



Aluminum steering column sectors and levers, spark and throttle control gears, switch keys, etc.

pressions, according to the piece. The Precision process, due to the pressure and power of the machines and the die construction employed, permits the use of unusually large dies and the casting of a wide range of combinations in one mold. We sometimes make an entire machine consisting of seven or eight parts in a single combination die, thereby greatly reducing die cost as well as casting cost, since a combination die of eight parts would not cost as much as two dies of four parts or four dies of two parts each. When combination dies are made, the parts should always be ordered in sets as it is not practical to make castings out of a portion of a die only.

Except in very plain cases, the only way to determine whether or not a part may be die-cast to advantage is to submit it for estimate.

In comparing estimates it must not be forgotten that you are buying service and skilled labor and not a stock commodity. The workmanship and service of no two die-casting companies are alike, just as the service of no two doctors, or engineers, or architects is alike.

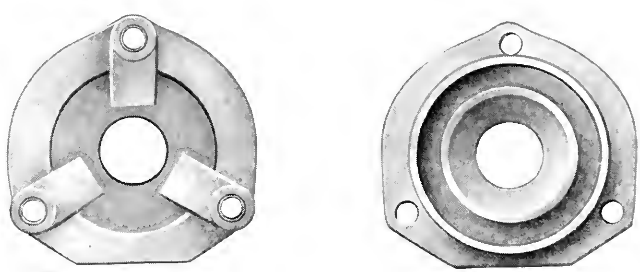
The work of the Precision Castings Co., Inc., has its own individuality and character. It is turned out by an organization of the most skilled men in the industry. Every detail has been worked out to its logical conclusion, making the Precision product a finished product in every sense of the word. Our chief inspector has assistants in every department who follow the work from beginning to end, preventing factory losses and delays and avoiding the production and shipment of defective parts.

We have frequently heard it said that the lowest bidder is entitled to the order; that he will be held to the specifications and the work returned if not found satisfactory. It is an error to assume that strict specifications may be made a substitute for good workmanship and service.

The cost of applying specifications that are not respected, the manufacturing delays, the losses due to defects discovered only after work has been done on the castings, must all be added to the lowest bidder's quotation, unless he can demonstrate his ability and the high character of his product.

It is our fixed purpose to keep Precision Die-Castings and the service back of them up to the highest commercial standards and quote the lowest prices that this policy will permit.

Estimates are prepared from models or blue prints, preferably models, or both when the model is not accurate. In die construction, when both models and prints are submitted, we follow the prints if there is any difference. When any doubt exists as to the suitability of the metal we propose to use, it should be thoroughly tested. We will furnish ingots for this purpose from which the parts to be die-cast may be poured in sand and machined to size. If the parts are found satisfactory, our die-castings will be found even stronger and better, due to the added strength given by the pressure and rapid chilling in the dies.



Aluminum pump shaft housing cover. Liberty motor.

The information given when orders are placed or estimates requested, should be as complete as possible. We suggest that the following points be given consideration and that we be advised fully concerning them:

1. Electrical conditions under which the parts will be used.
2. Temperature conditions—will they be subjected to heat or cold.
3. Will they be used indoors or out.
4. Will they be subjected to hard shocks, strains or wear.
5. If there are bearing surfaces under what loads and speeds will they operate.
6. Will the parts come in contact with water, moisture, gases, or corrosive liquids.
7. Will they come in contact with foods.
8. Will the parts be finished—if so, how (plated, baked or cold enameled, polished, etc.).
9. How will the parts be assembled and used.
10. When several parts are submitted they should be numbered or named to avoid confusion.
11. If they must fit other parts not furnished by us, such parts should be furnished, with suitable gauges and the kind of fit specified.
12. If several parts are wanted, will they always be ordered in sets so that they may be made in combination dies.
13. Between what points, if any, is special accuracy required.

When a complete model or an assembly print of the device in which the parts will be used can be furnished, it is always best to do so, as most of the information needed is usually conveyed by the model itself. New inventions or devices or designs not yet published or on the market will, of course, be treated as confidential.

New devices should be thoroughly tested and exact models built before the dies are constructed, as it is sometimes expensive and difficult to alter dies.

Our wide experience in applying the use of die-castings to every field in which they are used, makes the services of our engineering department very valuable to our customers. Our engineers will gladly assist in the design of parts and prepare sketches or drawings embodying their suggestions. Their advice on the latest and most approved methods of handling, finishing, assembling and machining die-castings will be found of valuable assistance.

Aluminum mold insert for cord tires.

III. Metals

Conditions which Restrict the Selection of Metals Used

The process is such in its very nature that only a very limited number of alloys can be die-cast commercially. Such metals must have a fusing point and shrinkage which will not be so great as to injure or destroy the metals of which the dies and casting machines are made.

The molten metal to be die-cast must be held in a compression chamber and subjected to high pressure. Metal must be used for the compression chamber, since no other material has the required strength and wearing qualities at the necessary working temperatures.

Metals when molten have a tendency to alloy with other metals coming in contact with them, even though such metals are far below their fusing temperature. For instance, molten zinc in an iron pot will eat away part of the iron and gradually destroy the pot. The dissolved iron forms an alloy with the zinc and after an excessive amount of iron has been absorbed, the zinc becomes unsuitable for use. The metals which may be die-cast are therefore first limited to those which may with practical results, be handled in metal pressure chambers and dies.

Parts for motors, instruments, cameras, stamp affixers, etc. Aluminum, tin and zinc alloys.

The degree of pressure applied has a marked effect on the grain and quality of the work. Pressures applied by the Precision process vary from 200 to 1000 pounds to the square inch, according to the work to be produced. The casting or pressure chamber must therefore have a high tensile strength at temperatures ranging between 800° and 1300° F., the points between which die-castings are poured.

The velocity at which metals enter the dies is tremendous, and at the temperature used will quickly destroy dies made from poorly selected metals or not properly treated and prepared.

The shrinkage of castings in the dies subjects them to great strain and wear. This problem does not exist when casting in sand, as in that case the metal in shrinking carries the mold with it.

Phonograph elbows, tone arms and sound boxes. Zinc alloys.

The metal to be die-cast, when solidifying, must have a certain amount of elasticity, as otherwise in shrinking against cores in the die, it will crack.

Aluminum alloys subject the portions of the dies against which they shrink to great wear, as they have a high shrinkage and fall substantially below their fusing point before being removed from the dies. It is apparent, therefore, that when the shrinkage and tensile strength of the metal to be die-cast exceeds a certain point, no die material may be found which will withstand the strain.

Another important consideration in determining the metals which may be die-cast, is the necessity of maintaining the metal continuously in a molten state in the machine or in an adjacent crucible. In some metals this causes excessive oxidation and occlusion of gases and impurities, resulting in porous, imperfect castings of low tensile strength.

This condition does not exist in sand molding, as the molds are first prepared and the entire pot of metal then poured in a comparatively short space of time. The die-casting machine operates only one mold, but works it continuously, requiring that a given quantity of metal be constantly in readiness for casting.

The metal formulas used by us are the result of long study and many experiments, as well as of our observation of die-casting metals in use over a long period of years. There are a great many important considerations which govern these formulas and guide us in the selection of the metals used for any particular work. These considerations involve the conduct of the metal in the casting machines almost as much as the strength and lasting qualities of the castings. Strong, solid and accurate castings cannot be produced from metals which by reason of their sluggishness, shrinkage, fusing point, tendency to dross, brittleness at high temperatures below fusing, etc., seriously interfere with production in the casting machines.

For these reasons it is very important that the formula be strictly maintained. This is not an easy matter when metals are kept in a molten condition for long periods due to their tendency to separate in layers according to their specific gravity.

While the molten metal is in the casting machines we constantly stir it by means of a device attached to the machine, keeping the formula constant and bringing oxides, gases and impurities to the surface.

Up to this time the difficulties involved in casting brass, bronze, iron, steel, nickel alloys, etc., have stood in the way of the successful commercial application of the process to these metals, although it is not unlikely that in the next few years brass die-castings will be produced commercially.

Die Casting Alloys

(See tables on p. 83.) The Precision Castings Co., Inc., maintains a laboratory in charge of the chief chemist, who also supervises the foundry in which all metals are mixed. He or his assistants, personally check up all weights before the metals are mixed to prevent variations in formula. All metals used in the foundry can be obtained from stock only on the chief chemist's requisition. The strictest supervision in maintained to avoid the production of inferior metals, either through insufficient or too much heat, and the temperature of all molten metals is constantly watched with pyrometers.

Our laboratory is specially equipped for the testing and treatment of white metals, and the men in charge have the advantage of many years of experience in this particular work. They employ the best methods for refining metals and know the sequence to be followed in combining the alloys. Pouring temperatures are carefully watched and the proper fluxes and de-oxidizers used. There can be no question, therefore, that the results obtained are the best that experience and modern science make possible.

Excessive impurities in die-casting metals are very harmful and also greatly reduce and hinder production. We use only the purest metals suitable for the

work. All metals are analyzed for impurities before acceptance, and rejected if they exceed our specifications in any particular. For this reason when metal cost is an important factor, we cannot always compete with concerns using the ordinary or low grade metals, although in many cases our manufacturing methods and equipment enable us to overcome this cost difference.

Aluminum Alloys

The most satisfactory aluminum alloys die-cast are those generally known in the trade as aluminum-copper alloys and contain from 5% to 20% copper. Aluminum-copper alloys are stronger and harder than pure aluminum and are more easily finished and machined. The tensile strength of our die-cast copper-aluminum alloys runs between 18,000 and 21,000 lbs. to the square inch.

The high compressive strength of the copper-aluminum alloys is due to the formation of a needle-like eutectic (Al_2 cu. and Al.) which is imbedded in practically pure aluminum. They have nearly the same general chemical properties as pure aluminum.

Comparative figures of the properties of sand and die-cast No. 12 alloys (92% Al. and 8% copper), show that the die-casting has 20% more elastic limit and almost double the percentage of elongation.

The addition of copper to aluminum, besides increasing the tensile strength, reduces the fusing point and shrinkage, making the metal more suitable for die-casting.

In die-casting aluminum it is not always practical or desirable to hold to any particular copper content, but this may be increased or reduced as the casting conditions warrant. Die-castings may be made with satisfactory results with as much as 21% or 22% of copper, when the design of the piece or its functions require. More than 23% copper is rarely, if ever, used. When casting in sand more than 8% or 10% of copper is not frequently used, as the slow cooling permits the formation of large crystals and in consequence produces a brittle metal. The rapid and almost instantaneous chilling which takes place when these alloys are die-cast prevents the formation of large crystals and therefore produces a very much tougher metal.

Zinc strengthens aluminum more than copper or manganese, but it is not suitable for die-casting as the high temperature at which the metal must be maintained for extended periods causes it to burn out and dross excessively, destroying the good qualities of the alloy. These metals should only be used under conditions which permit immediate pouring after melting.

The presence of zinc in aluminum-copper alloys causes a great number of the needle-like eutectic to be thrown out, so that the copper content must be decreased as the zinc is raised. European practice has favored these alloys over the aluminum-copper, owing to their somewhat greater tensile strength, but in American practice the zinc is generally omitted. It has been asserted that zinc-copper-aluminum alloys fail in time under stress, but this has not been satisfactorily proven. They should not be die-cast because of the drossing of the zinc. In saline solutions, galvanic action causes such alloys to deteriorate rapidly.

Tin has never been a satisfactory metal for use in conjunction with aluminum in die-casting. It makes the metal too brittle, its brittleness increasing in time, and the alloy is not as strong. As tin is also expensive it is rarely used.

Manganese-aluminum alloys may also be used, but unless used for special purposes they present no substantial advantage in strength or general commercial qualities over the copper-aluminum alloys.

Under normal markets aluminum, though comparatively high in cost per pound, is really no more expensive than the cheaper white metals, due to its low specific gravity. For instance, a casting weighing one pound in No. 12 aluminum alloy will, if made in the following metals, have these weights:

Copper	3.2 lbs.
Brass	3.0 "
Cast Iron	2.6 "
Lead	4.0 "
Zinc	2.5 "
Bronze	3.1 "

Lead and aluminum do not "mix", having no affinity for each other. Lead is a harmful impurity in aluminum, but can only be present in very small amounts as the metal will not "hold it". Tin in aluminum-copper alloys is harmful. It causes excessive brittleness in time and the castings will disintegrate. Not more than 1½% to 2% of iron should be present in aluminum alloys as otherwise the metal will become too brittle. Below that amount iron is not harmful.

Aluminum brush holders for electric motors. Electric instrument frames, tin alloys.

Properties of Pure Aluminum

Pure aluminum is not generally used for castings because it is softer and more porous than its alloys. Its strength and hardness are considerably increased when it is compressed or rolled. It may be rolled in sheets .005″ thick. Gold alone is more malleable. The metal has excellent tonal qualities which are improved by the addition of silver.

The electrical conductivity of the pure metal is about 62 in the Matthiessen Scale. It is practically non-magnetic and is an excellent conductor of electricity. It is sometimes used for power feeders and high tension transmission lines.

Its heat conductivity is greater than zinc, iron, tin or steel, and is exceeded only by copper among the baser metals.

The specific gravity of ordinary grades is 2.68, making it about ten twenty-sevenths the weight of cast iron.

Shrinkage per foot is .2031″. Its linear expansion is exceeded among the common metals by zinc and lead only.

Aluminum melts at 657° C. or 1215° F. and develops weakness at solidification tending to cause cracking, due to the absorption of oxides, silicates, and other impurities, and its high shrinkage.

Chemical Properties of Aluminum

The natural solvent of aluminum is hydrochloric acid. It is slowly attacked by either concentrated or dilute sulphuric acid, but the hot concentrated acid dissolves it readily. Cold dilute or concentrated nitric acid have little effect and act but slowly when hot. It is not affected by sulphur at less than red heat.

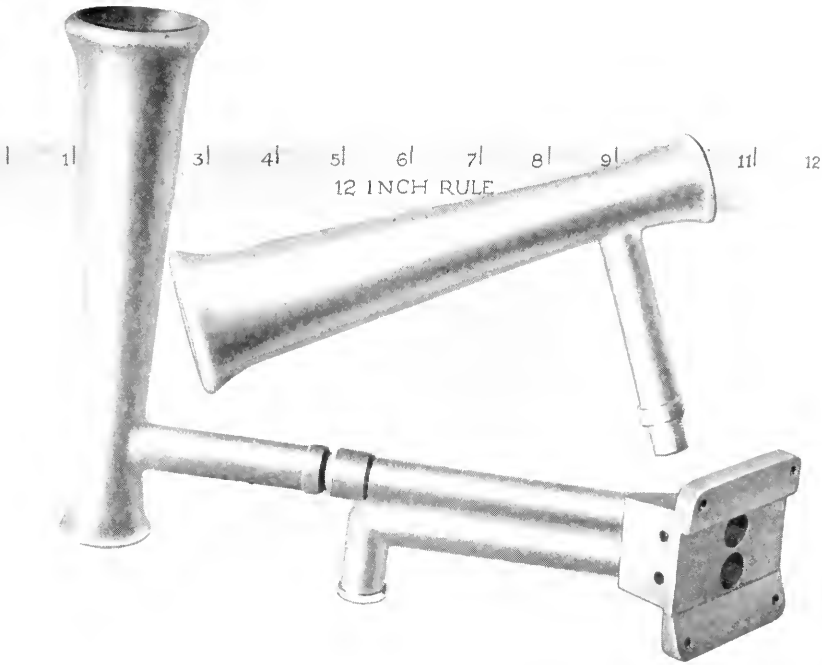
Organic secretions and salts have little effect, and vinegar (4% acetic acid) practically none. For this reason it is sometimes used for dental plates and surgical instruments. The acids in foods have little effect and when any action takes place the chemical products are harmless, which makes the metal well suited for kitchen ware.

Contrary to an impression frequently held, it is not affected by mineral and sea waters. Strips of aluminum were placed on the side of a wooden ship and were found to be corroded less than .005″ after six months exposure to sea water, whereas copper under the same conditions corroded nearly twice as much.

Aluminum may, however, be made to corrode rapidly in salt water by being held in contact with another metal such as copper or iron, causing galvanic action to take place.

As most metals are electro-negative to aluminum, a voltaic couple is formed under such conditions, resulting in the rapid corrosion of the electro-positive metal. When, therefore, aluminum is used under such conditions, it should be insulated from the electro-negative metals with a good insulating material such as rubber, or a heavy coat of insulating paint.

Aluminum is not attacked by carbonic acid, carbonic oxide, or sulphuretted hydrogen.



Aeroplane speedometer made for the U. S. Government. Aluminum. Measures speed by wind velocity.

Aluminum has been said to absorb nitrogen from the air, causing it to deteriorate, but experiments recently made have proven that the metal does not absorb any nitrogen bubbled through it for several hours, although it may under such conditions retain a minute trace to no harmful extent.

Solutions of caustic alkali, bromide, chlorine and hydrofluoric acid attack the metal quickly.

The common impurities are silicon and iron. Aluminum has a great affinity for iron, being in the same chemical group. Impurities in excessive quantities materially reduce the resistance of the metal to corrosion.

Zinc Alloys

(See tables, p. 83.) Zinc alloys containing various proportions of tin, copper and aluminum or only one or two of these metals, have been used since the inception of the die-casting industry. They are comparatively cheap among the white metals, but considerably more expensive than cast iron, which they resemble in strength and brittleness.

Precision zinc alloys vary between 12,000 to 16,000 lbs. tensile strength to the square inch, according to the design of the part and formula used.

They may be plated, finished and machined as described under separate headings. They should not be used for food containers, and are corrosive in contact with moisture. They should not be used under heat conditions exceeding about 150° F., but may temporarily be subjected to between 250° F. and 300° F. according to the formula.

Pure zinc is too brittle and soft to be die-cast and flows sluggishly. When alloyed with tin, copper or aluminum the crystals are materially reduced, producing a finer grain and a much tougher and stronger metal; its shrinkage is also thereby reduced and it flows more readily. The rapid chilling in the die greatly increases the strength and toughness of the metal.

Tin alone does not increase the tensile strength or hardness but softens the metal, makes it flow more readily and prevents a certain amount of shortness or cracking. In excess of about 8% it performs no useful function and does not combine well.

Copper toughens and strengthens the metal but should not be added over $3\frac{1}{2}\%$, as then it increases the fusing point to such an extent that excessive drossing and oxidation are caused in the casting machines.

Aluminum is a wonderful de-oxidizing agent, reducing the dissolved or imprisoned oxides within the metal and forming alumina which floats on the surface

Upper center and lower left, swivel joints for flexible speedometer shafts. Other parts instrument and speedometer frames. Zinc alloys.

and is skimmed off. It is also valuable because it forms a very thin coating of aluminum oxide on the surface of the die-casting which prevents the alloy from soldering or sticking to the dies, due to the affinity of zinc for iron. Aluminum in small percentages also makes the metal flow more readily and its de-oxidizing qualities strengthen and toughen the alloy. More than $\frac{1}{2}\%$ of aluminum should not be added in zinc alloys containing tin, as this will cause deterioration. (See last paragraph below.)

All metals when molten have a tendency to absorb atmospheric and fuel gases; oxides also are occluded and held mechanically within the metal. This latter property is well illustrated in the thick scum on the surface of zinc alloys before fluxing, which consists of an intimate mixture of metals and oxides, and rises to the top because of its lower specific gravity. To free the metal from oxides the most suitable flux used is sal-ammoniac. This decomposes into ammonia and hydrochloric acid; the volatile chlorides free the metal from the oxides and the clean oxides are then skimmed off the surface.

Properties of Pure Zinc

Zinc, or spelter as it is known in the trade, is a bluish white metal, hard and brittle and coarsely crystalline when the pouring temperature is much above the melting point, but more granular when poured near the melting point, which also makes it more malleable and more resistent to acids. Rapid chilling greatly reduces the size of the crystals.

In dry air, pure zinc retains its lustre, but moisture causes it to become covered with thin greyish white coat of basic carbonate which protects it from further corrosion. Pure zinc in sheet form was exposed on a roof in Bavaria for 27 years and showed oxidation of only .004".

In the presence of impurities or when cast with other metal, it loses its non-corrosive qualities to greater or lesser extent, according to the circumstances.

It is not blackened by hydrogen sulphide fumes or solutions as are copper, silver, lead, etc. It dissolves readily in nitric acid, but when pure is almost insoluble in other acids. Ordinary zinc (prime western grades) will dissolve in hydrochloric (muriatic) and sulphuric acids. Caustic alkalies dissolve it more slowly.

With the exception of aluminum and magnesium, zinc is the most electro-positive of the common metals. In consequence it is easily dissolved when in the presence of caustic alkali and in contact with electro-negative metals, such as iron, tin or copper, all of which are below aluminum in the electro-chemical series. (See table, p. 86.) A high percentage of aluminum in the zinc-tin-copper alloys is undesirable for the same reason. Under these conditions a voltaic couple is formed, resulting in the immediate and severe attack of the electro-positive element by the electro-motive force produced by the difference in potential or chemical action of the negative and positive metals.

It is for this reason that zinc alloys containing copper, tin and aluminum are corrosive in the presence of moisture. By care in the preparation of the alloy

this corrosive action may be reduced. With this end in view, alloys of zinc made up in the Precision laboratory are very low in impurities and when tin and aluminum are both present the aluminum content is held to very low limits.

Impurities in Zinc

Low grade spelters should not be used when the quality of the die-casting is a consideration. They affect the lasting qualities of the metal, weaken it, and produce a poor finish.

The common impurities are lead, iron, cadmium and arsenic. Under the proposed revision of standards as of March 8, 1917, the American Society for Testing Materials divides spelter into five grades as follows:

	% Lead	% Iron	% Cadmium	Total % not over
High Grade*	0.07	0.03	0.07	0.10
Intermediate*	0.20	0.03	0.50	0.50
Brass Special*	0.60	0.03	0.50	1.00
Selected*	0.80	0.04	0.75	1.25
Prime Western	1.60	0.08		

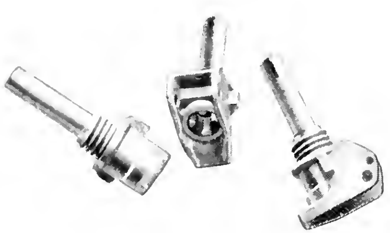
*It shall be free from aluminum.

Cadmium over .30% makes the metal short, and causes cracks in shrinking.

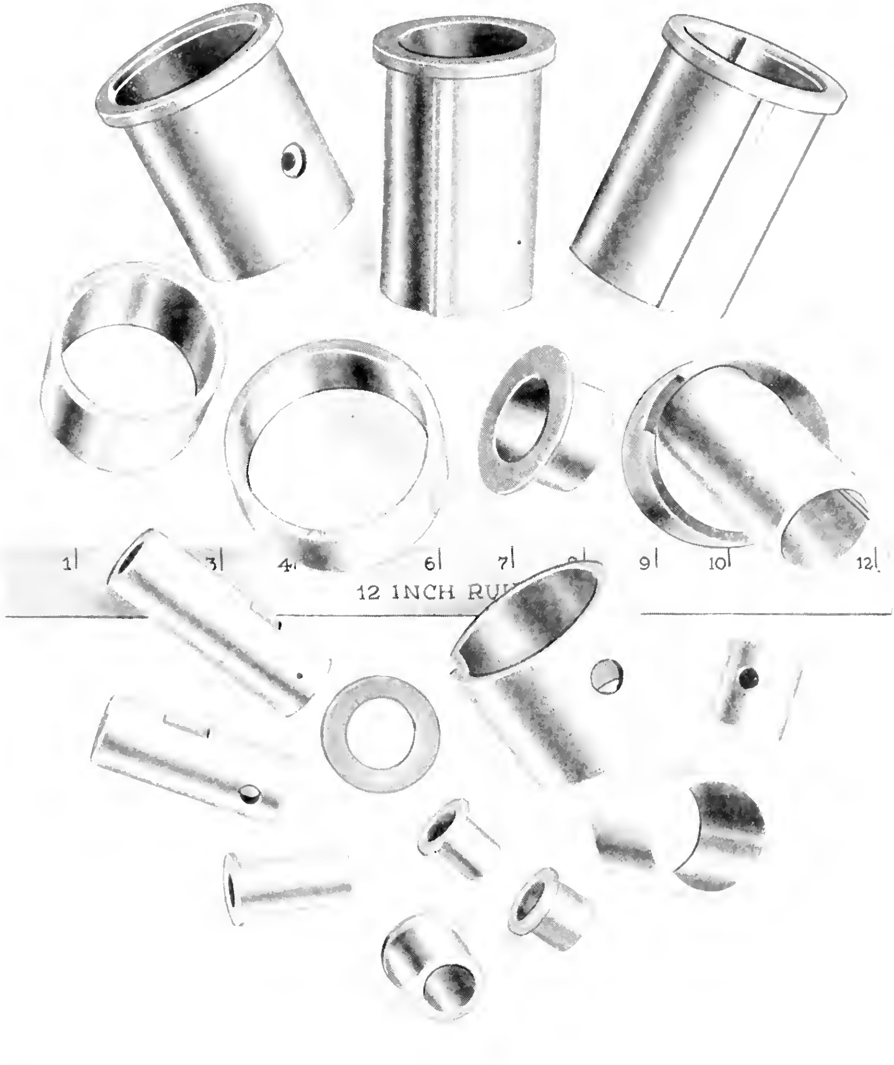
Lead is not as injurious as cadmium, arsenic or iron. Zinc cannot hold more than 3% of lead except when liquid. At 788° F. it will hold 1.7% and at 1200° F. 5.6%. Lead should not be present in zinc die-castings over 1%.

Iron above .15% tends to make the zinc brittle. In substantial proportions it makes the metal easily reducible to a fine powder. A certain amount of iron cannot be kept out of die-castings, as the metal is absorbed in the pots of the machines.

Arsenic over .05% has the same effect as iron and in large proportions, due to its great affinity for iron, will cause the metal to attack the iron pots and parts of the die-casting machines more rapidly.



Bouchon for hand grenades. Over 25,000,000 made for the U. S. Government.



Babbitt bushings.

Tin Alloys

(See tables, p. 83.) Tin when die-cast is usually combined with varying proportions of antimony, copper and lead or only one or two of these metals. It may also be cast pure. Tin alloys are not brittle, they have low tensile strength but are easy to cast because of their low fusing points and the fact that the metal flows readily in the dies. Very small or delicate parts which cannot be cast in zinc or aluminum alloys are for that reason often made in tin alloys. Their low shrinkage makes them more accurate and largely avoids cracks in casting.

They are not corrosive in the ordinary acceptance of the term and may be used for parts coming in contact with food when no lead is in the alloy. They are not affected by moisture and are slowly affected by alkalies and mineral acids.

One of the chief uses for the tin alloys is in the composition of bearing or anti-friction metals known as babbitts.

Lead Alloys

(See table, p. 83.) Lead is usually alloyed with tin and antimony; in substantial proportions it will not readily alloy with copper, except in the presence of tin and antimony, and at a temperature and under conditions which render it impracticable for ordinary uses and particularly for die-casting.

Lead alloys should never come in contact with food, as organic acids react with them, forming basic lead salts which are poisonous. They are insoluble in dilute sulphuric acids, dissolve slowly in hydrochloric, and readily in nitric acid. They are not affected by moisture and are non-corrosive in a commercial sense on exposure to the elements.

They are cheaper than the tin alloys, but not nearly so tough. They have similar casting properties and are greatly toughened by the rapid chilling in the dies.

Type metals all have a lead base and are made to various formulas according to the requirements. There is no standard type-metal formula and when used outside the printing trades it is usually understood to contain merely lead, hardened with antimony. One class of type metals used for printing contains:

Lead	77%	to	53%
Antimony	18%	to	26%
Tin	5%	to	18%
Copper	0	to	3%

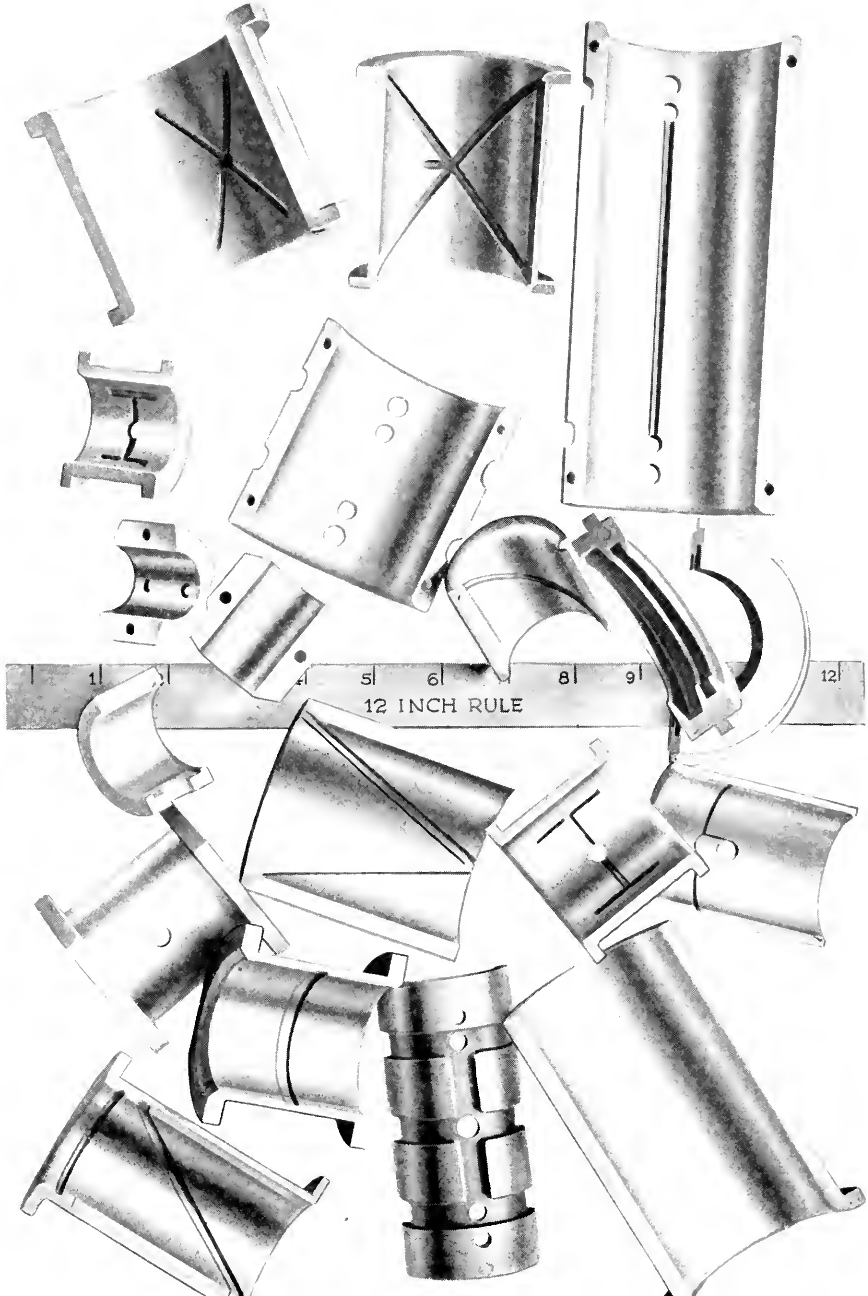
The metal used in linotype machines contains about:

Lead	83%
Antimony	14%
Tin	3%

Anti-Friction Metals or Babbitts

(See tables, p. 83.) In a perfectly adjusted and lubricated bearing, there would be a thin layer of oil between the journal and the bearing; the metals would not actually touch each other at any point and the friction would not be between the metals themselves but between the metals and the film of oil. Such a perfectly adjusted bearing is never attained in practice and the purpose for which babbitts are designed is to overcome the harmful effects which are brought about by actual metallic contact between the journal and the bearing due to the necessarily inaccurate and uneven surfaces.

This is done in two ways; first, by making the body of the bearing metal plastic enough to conform to the inequalities in the journal, thereby fitting itself as perfectly as possible; and second, by making the bearing surface as hard as possible to reduce friction and wear.



Babbitt bearings for combustion motors.

The softer a metal, the greater is its co-efficient of friction. Hard metals require greater pressure to produce the same friction as soft metals.

Hence alloys containing hard crystals imbedded in a plastic matrix answer the general requirements of most bearing metals, the hard cystals reducing the frictional contact, and the body or matrix adjusting itself to the size of the journal.

A representative babbitt formula is:

Tin	89.1%
Antimony	7.2%
Copper	3.7%

In this and similar metals two groups of metallic compounds are formed, one of tin and antimony corresponding to the formula Sn Sb (49% tin and 50% ant.), and the other of tin and copper, corresponding to the formula Sn Cu_3 and Sn Cu (Sn Cu_3—38.5 tin to 61.5 copper), and (Sn Cu—55 tin to 35 copper). These compounds form the hard crystals which furnish the anti-frictional qualities of the metal.

By adding a small percentage of aluminum, babbitts are made considerably closer in grain, resulting in greater durability and wearing qualities. The rapid chilling in the mold when die-cast also toughens and strengthens the metal to such an extent that hammering or compressing the bearings is unnecessary. Bearings poured in hot molds or not chilled are considerably softer, and to give good results must usually be compressed before they are assembled in a combustion motor. The general practice is to set them up and run through an expansion roller. If this is not done such bearings will compress in service, leaving too much clearance between the bearings and the shaft.

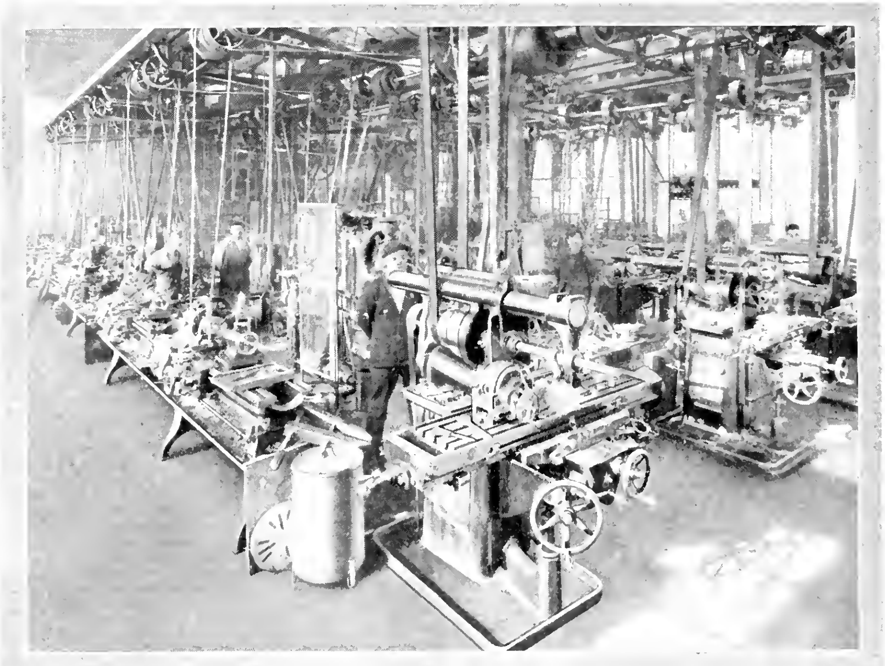
For many purposes, when pressure is light, antimonial lead alloys are among the best bearing metals known. Combined in the proportion of lead 87% and antimony 13% a eutectic is formed which is four times as hard as lead. When the antimony content is raised, crystals of free antimony are held within the eutectic, and when these crystals become numerous enough to come in contact with each other, the load on the metal, instead of being transmitted through the eutectic, is taken up by the antimony crystals, and the metal is too brittle for use. This is the case when more than 23% is used.

Copper up to 2½% will raise the fusing point of such alloys and toughen them. Tin may also be added which will reduce the fusing point and toughen the metal. When high pressures are encountered, tin is a desirable element up to 10%, reducing brittleness and lending rigidity to the bearing. Lead bearing alloys, when used for heavy loads or under conditions which develop heat above about 250° F., should not contain more than 10% of tin, as more than that will reduce the fusing point and cause "squeezing out" when the bearings run hot.

We have manufactured babbitt bearings for the largest motor builders for years, having grown up with the automobile industry. "Precision" bearings are favorably known wherever motors are built. Our metallurgical chemists and engineers have succeeded in producing a series of babbits of various grades which,

while equal to the finest babbitts made for the general trade, are at the same time designed so that they will be toughened and hardened more by the die-casting process we subject them to, than ordinary metals.

Ball bearing retainers and babbitt bearing shims, tin and zinc alloys.



Precision Castings Co.'s die shop in Fayetteville plant.

IV. Dies, Die-Design and Construction

Die-casting dies probably present more difficulties in design and workmanship than any other dies. Their life depends entirely on their construction, the character of metal used both for the die and the castings made in them, the design of the piece to be made, the care they receive, etc. Naturally, a die for a delicate piece, having many moving slides and cores, will not last as long as a simple die under the same conditions. The important part which workmanship and material play in the life of a die, as well as in the quality of its product, cannot be emphasized too strongly. The wise buyer will never question a die charge if other factors are satisfactory. Some dies are good for 25,000 castings, others for a million. Precision dies are built for endurance irrespective of expense, as we are equipped especially for quantity production and consider the best dies the cheapest in the end. We shoulder a large part of the die cost ourselves to avoid any tendency on the part of customers to save unwisely in such expenditures.

Causes of Inaccuracy in Castings

Although design and construction have a most important bearing on the accuracy, finish, and grain of the castings, it is frequently very difficult to determine whether defects in castings are due to dies or other causes.

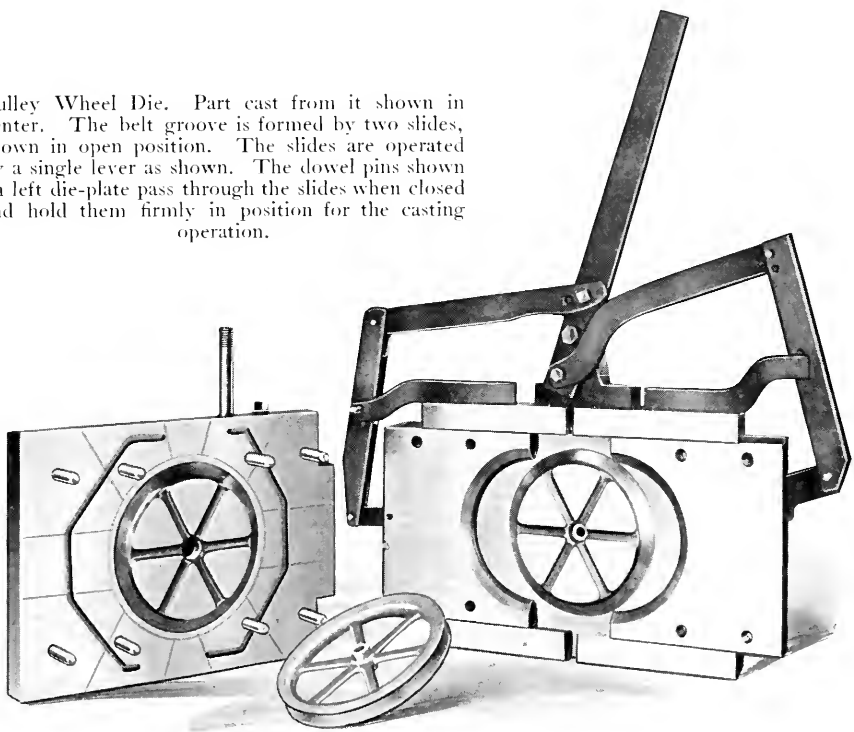
Inaccuracy may be due to a number of causes. If constant, i. e., alike in all castings, it is almost always due to an error in the size of the die, or a shifting or warping of the die parts.

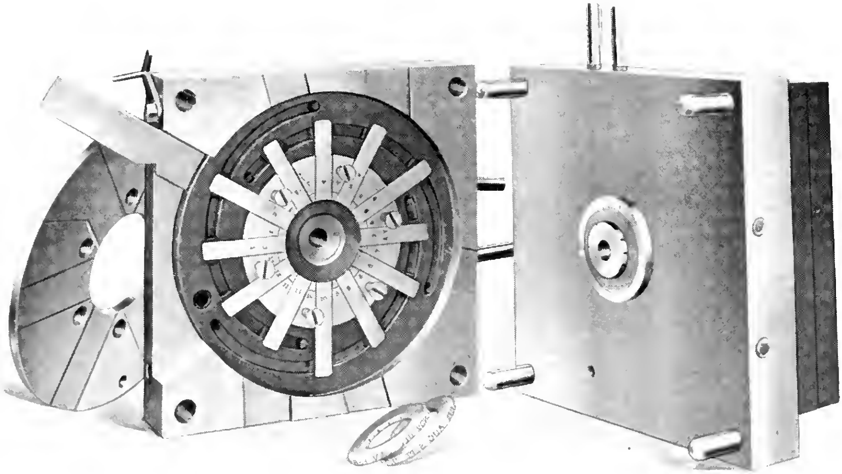
Precision dies are cut from solid blocks whenever possible. This is often more expensive than "building up" an impression but it is much more satisfactory in results. Many constructions, due to the design of the part, must be "built up" out of several pieces and in such work the greatest care should be used.

Molten metal under high pressure will creep into the slightest crevices. All die parts must therefore be perfectly fitted. The high pressure and hard wear to which they are subjected require substantial construction. Long practical experience is necessary to properly direct work of this kind.

The heat at which dies are worked and the constant heating and cooling which take place will cause them to warp badly if steps are not taken to overcome this. For this reason all dies are heat-treated to take all the internal strains out of the metal and protect its surfaces from the destructive action of the molten metal.

Pulley Wheel Die. Part cast from it shown in center. The belt groove is formed by two slides, shown in open position. The slides are operated by a single lever as shown. The dowel pins shown on left die-plate pass through the slides when closed and hold them firmly in position for the casting operation.





Number Wheel Die. Engraving is formed on the 12 slides. These slides are fastened to rollers which travel in the cam slots in the circular plate, back of the slides. By moving the lever attached to the plate back and forth the slides are withdrawn or put in place. The plate on the extreme left fits over the slide mechanism to protect it. The die is gated through the center, a sprue cutter being used.

When inaccuracy varies in different castings of the same run it may be due to a number of causes. If the error is across the parting line it may be due to particles of dirt or metal on the die surfaces, holding them apart. In old style casting machines it may be due to wear in the clamps and toggles used to hold the dies shut, or to their weakness. When a casting is made, the pressure under which the molten metal enters the die has a tendency to open the dies and when large castings are made the strain on the dies is great, running as high as 15 tons.

Precision power driven die-casting machines do not use clamping devices and are not dependent on mechanical means to keep the dies closed. They are held shut under much greater pressure than is exerted to open the dies, so that there is no likelihood of undue variation from this cause in our work.

Undue variation in die tempearture, especially in large parts, also causes inaccuracy. There are a number of features in our process peculiarly suited to die temperature control in that the operation of the machines is constant and steady, the die position fixed and temperature fully controlled.

Precision dies are water-cooled and their temperature control lies in the means of regulation used to control the flow of water, but if the operating conditions are unfavorable, such as irregular operation and heats, temperature control is useless.

If moving parts of dies are cheaply constructed through a desire to save time or material cost, or through inexperience, a great many difficulties may beset the way of the user as well as the producer of die-castings. Metal pressure may open or shift cores. If they are not properly fitted and lubricated wear will result, causing inaccuracy.

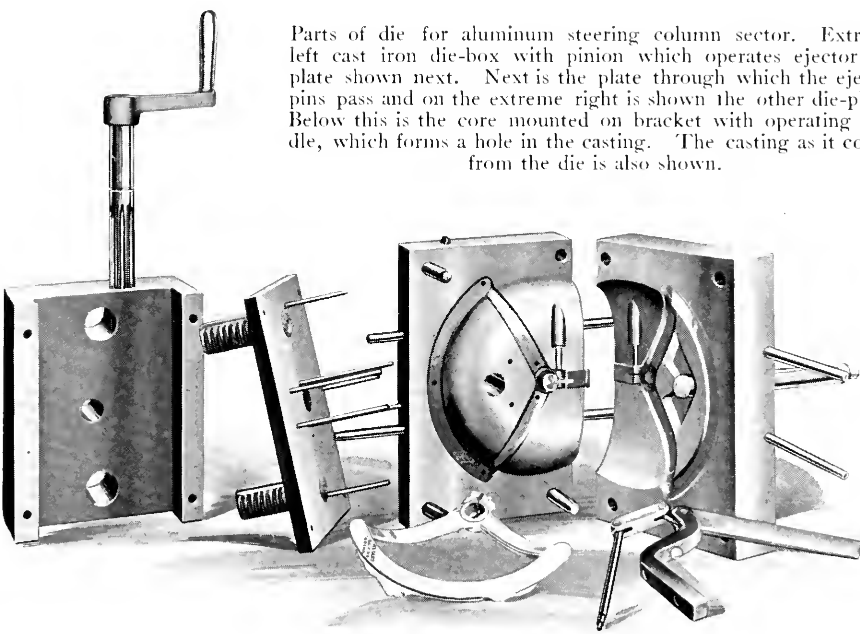
Dies should be so constructed that they may easily be taken down and thoroughly overhauled and cleaned after a certain period of use.

Die Assembly

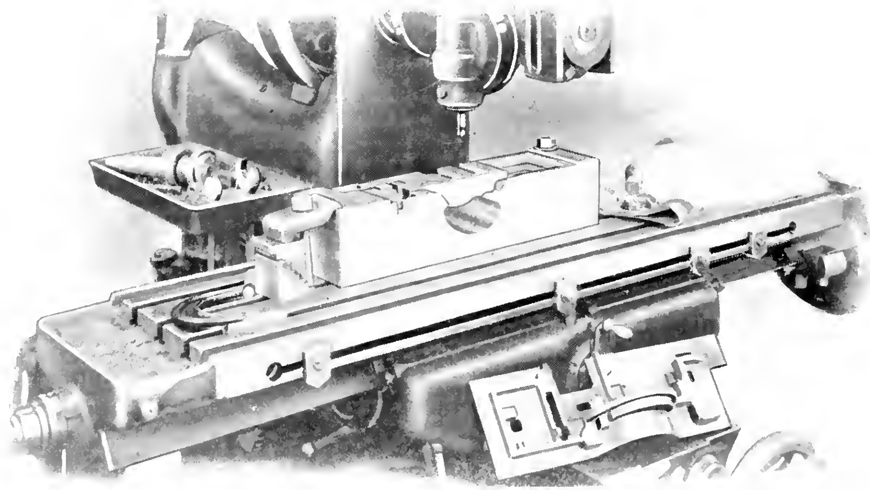
Each die is complete in itself and holds all the operating mechanism needed for its use. Attached to the ejector pin side of the die is an iron box, in which are mounted core and ejector pin plates which are operated by rack and pinion. Separate slides and cores are mounted on the die according to the design of the part to be made and are operated with handles or gears. They are usually fitted with safety devices to prevent improper operation, and locks to prevent their being moved by the metal pressure.

Die Surfaces

All die surfaces coming in contact with molten metal must be polished for finish and to prevent the castings from adhering to the dies. All surfaces rubbed by the castings in ejection can have no tool marks or depressions and must be absolutely smooth and slightly tapered to free the casting the moment it begins to move out. The amount of taper depends on the circumstances in each case (see page 52). Theoretically a casting could be



Parts of die for aluminum steering column sector. Extreme left cast iron die-box with pinion which operates ejector pin plate shown next. Next is the plate through which the ejector pins pass and on the extreme right is shown the other die-plate. Below this is the core mounted on bracket with operating handle, which forms a hole in the casting. The casting as it comes from the die is also shown.



Die block in process on milling machine. Below is shown wood pattern of the part to be made. Note that the die impression is being milled out of a solid piece of steel instead of being built up in sections.

withdrawn without draft but in practice it is impossible to maintain an absolutely true surface without warpage. The slightest undercut will crack the casting in ejection.

Gating

The gating of castings is the subject of constant study and no fixed rules can be applied. Castings, according to their size and design, are affected by the width, thickness, shape and location of a gate as well as by the direction in which it enters the casting. Improper gating will cause poor finish and porous castings.

Die Materials

For tin, zinc and lead parts the die impression is made of machine steel. Except for special purposes it should not be hardened as the expansion and contraction will cause it to crack and check. Cast iron is seldom used for die impressions because its porosity has a tendency to make castings stick to it and show poor finish. It is not as easily worked as soft steel and cannot be hobbed.

Drill rod and tool steels are used for ejector pins and cores, slides, etc. Soft machine steel cannot be used for aluminum. We have developed several special alloy steels for aluminum dies which have given wonderful service. In several instances over 200,000 castings were taken out of a single die.

Shrinkage Allowance in Dies

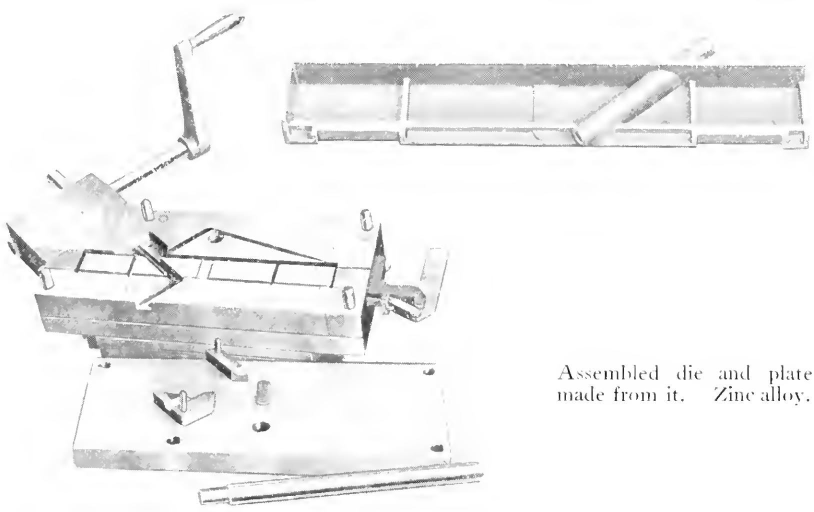
Shrinkage of castings is allowed for in the dies, so no allowance should be made in drawings or models. When simple pieces are made this allowance may be calculated accurately. The shrinkage of complicated pieces is held

back by portions of the die against which they shrink and the amount of shrinkage in many such cases can only be approximated. Long experience develops great skill in this respect and by working "safe", that is so that by taking a little more metal from the die any inaccuracy may be overcome, wonderful results are obtained.

Changes

Changes in dies may be made but it is best to avoid them as much as possible. The die is the exact opposite of the part to be cast, therefore, to add metal to a part it need only be taken away from the die, but when on the other hand it is necessary to add metal to a die, the task is frequently a difficult one. It may be done by inserting pieces in the form of plugs or strips, but it is not practical to weld pieces to a die-impression. Changes frequently weaken the die construction or compel the use of inferior methods of die construction, which could of course be avoided if the die had been laid out for the final design in the beginning.

It is much better to take the time to build models and thoroughly try out all changes or new designs before building or changing dies. There should be no element of experiment in the production of die-castings as the process can only be used economically for quantity production of identical parts, and the dies should be used as first designed.



Assembled die and plate made from it. Zinc alloy.

Crossing and Interchangeable Cores

It is better practice to avoid cores or slides which pass through each other. A small core passing through a large core is apt to strike the larger core, raising a burr, or injuring one or the other core. This will occur if the smallest particle of dirt prevents the larger core from taking its proper position. When the design cannot be modified to avoid die construction of this kind it is usually better to machine or drill that part of the casting which requires the undesirable die construction.

When two or more parts of the same general design, but differing only in one or two details are wanted, it is frequently possible to make them from a single impression by using interchangeable plugs or cores in the die.

Combination Dies

When combination dies containing two or more impressions of different parts are used, it is not good practice to shut off any of the impressions so that only certain ones may be cast, but the entire set must always be made. For this reason such dies should not be made unless the parts will always be used and ordered in complete sets.

Die maker "Checking Up."

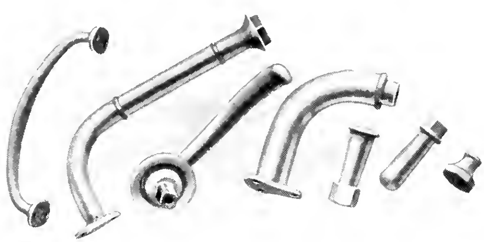
Removal of Dies

Precision dies are not removable although they are held for the exclusive use of the customers to whose order they are made and who pay part of their cost. We include only a portion of the die cost in our die charge. The rate charged is less than the actual hourly cost of the work to us. We assume full responsibility for the perfect condition of the dies perpetually without charge, except when changes which affect their design are ordered by the customer. We also provide for insurance and assume all the risk.

The design of Precision dies involves skill and experience, the result of many years of effort which we do not wish to make generally available. They are also best fitted for use on Precision machines and if used elsewhere would require material changes, which might produce wholly unsatisfactory results. Dies are easily injured in shipment or when handled by inexperienced workmen, owing to their delicate mechanism and heavy weight.

The removal of dies is not permitted by the leading concerns in the die-casting industry, and in other fields such as forging, stamping, rubber and composition molding, etc., a similar custom prevails.

The dies represent an investment on our part which will be useless to us without the good will and patronage of those for whom they were built, and it must always be our aim to make Precision Service high in its standards and attractive in cost (as has been our practice for many years), if the business of the company is to continue to grow and prosper.



Handles and knobs. Aluminum and zinc alloys.

V. Die-Casting Design

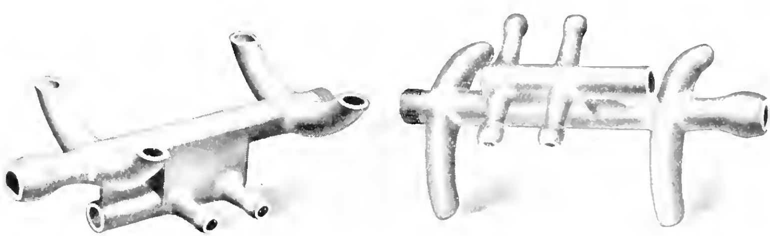
Die-castings present entirely different problems in designing the parts to better adapt them to the process of manufacture than do sand castings, forgings or machined parts. Slight variations in construction or design frequently greatly reduce the cost and increase the strength and efficiency of the parts without interfering with their functions. Only those who have a very wide and thorough experience in the art of die-casting, combined with a good knowledge of mechanical and production engineering, can take full advantage of the possibilities the die-casting process offers in these respects.

Among the numerous illustrations in this book are many in the designing of which our engineering department has lent valuable aid. This part of our service is always at the command of our customers.

Walls $1/16''$ and in some cases $1/32''$ thick may be cast, depending on the size and design of the parts and the metals used. The weight in zinc and tin should not exceed about 10 pounds, in lead about 15 pounds, and in aluminum about 3 pounds. The average size depends on the piece but seldom exceeds 24″ over all.

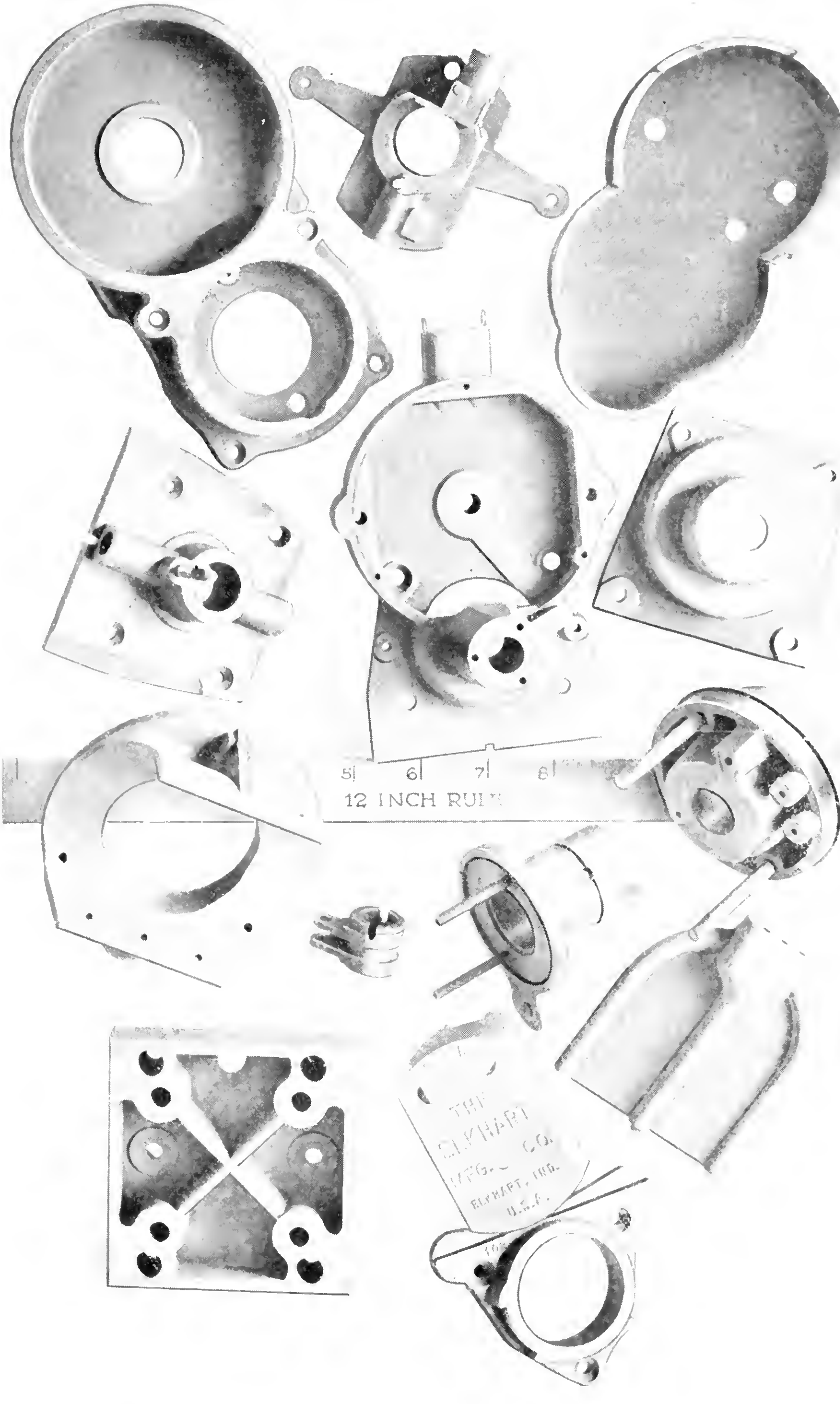
Strains and stresses on parts should be studied and met by proper thickness of metal and wall construction. Inserts, beads, fillets, lugs, and webs all play a part in the problem. Casting and shrinkage strains occurring in the casting operation must be considered as well as the comparative die cost of the various possible designs.

If a particular surface must be perfect and smooth it should always be so specified, as almost all castings have ejector pin marks made by the pins in ejecting the castings. The casting can usually be so placed in the die or the method of ejection so arranged that these marks will not show if proper information is received in the beginning.



Milking machine part. Tin alloy. If not die-cast, this part would have to be made of tubing soldered together. The tubes would have to be machined, bent, and expanded for the hose connections. The cost would be many times that of the die-casting which is also more accurate and rigid.

Magneto breaker box.



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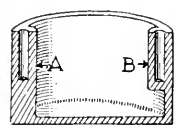
Aluminum and zinc alloys. *Breaker box.*

When parts are to be assembled as many parts as possible should be combined in one piece. But it sometimes happens that a piece is so large or difficult that it will be cheaper to split it. When this is desirable it can always be done so that the part may be assembled in a simple and inexpensive manner.

Undercuts

Undercuts are the surfaces of a part which, when formed in the die, would prevent the ejection of the casting unless provision is made in the die by means of moving parts to permit the part to pass out. The die opens at right angles to the parting line of the casting and it will readily be seen that to avoid undercuts the casting must gradually grow smaller above and below the parting line. It must always be remembered that every depression or irregular surface on a casting is not an undercut, as everything depends on how the part is placed in the die. In one position a part may have many undercuts and by being placed in another position these undercuts may disappear.

The methods of forming undercuts in dies are limited only by the ingenuity of the designer. The usual practice is to construct moving cores or slides, but sometimes this cannot be done. In such cases collapsible cores or loose pieces may be used. Such construction should, of course, be avoided as much as possible, as it entails delicate and expensive die construction and delays production. Collapsible cores are also more or less inaccurate, and cannot be properly cooled. They are used to better advantage in other methods of manufacture. Sand cores also have been tried but without success. They are inaccurate and the sand gets into the dies and machines, causing considerable trouble. The impact of the metal entering the casting breaks and chips them.



A shows proper construction for fastening lug.

B forms an undercut, preventing withdrawal of the core.

Fillets

Sharp inside corners should be avoided, as they cause shrinkage cracks and also weaken the part. All such corners should be filleted.

Metal at the great speed at which it enters the die does not flow as well around a sharp corner as when it is rounded. A sharp corner means a knife edge in the die and if the slightest surface crack occurs at this point the casting will break on slight pressure, in the same way that the cut of a diamond over glass causes the glass to crack.

Fillets should be as large as the design and functions of the part permit. When another part fits the edge to be filleted it should be rounded to fit the fillet. A radius of $1/32''$ or $1/64''$ is sometimes enough for the purpose if more is not permissible.

Beads

Beads are used for strength at the ends of tubes or thin surfaces or around slots or holes. They are also needed to help overcome cracking when the castings are made.

Parts of soda fountain pumps — tin alloys.
Assembled pumps shown
in the center.

Webs

Reinforcement by webs is better than by thickening walls. Heavy walls, when other adjacent walls are light, are usually only "dead" metal, adding little strength in proportion to weight and expense. The chilled surface of a casting is stronger than the inner sections, which are also more or less porous. In considering the design of castings this must be borne in mind in addition to the other well known engineering advantages of web construction.

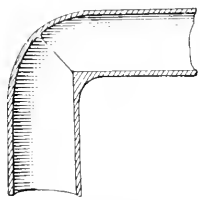
Elbows or Curved Holes

A curve in a hole presents an undercut preventing a straight withdrawal of the core. It is usual, therefore, when withdrawing cores in a straight line to make the inside angle of the inner wall of the elbow sharp, as shown in the illustration. This is the simplest and quickest method of producing such parts and therefore the least expensive.

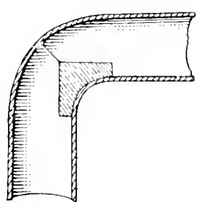
It frequently happens that this construction is objectionable and in such case we can produce almost any desired design.

A tapering turn and also curved inside walls with no taper at the turn may be cast as shown in the illustrations.

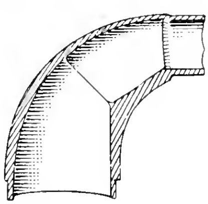
When the core can be withdrawn on an arc not exceeding about 100 degrees, no loose pieces in the die are needed. In such an event the end from which the curved core is withdrawn cannot have a straight portion at the opening.



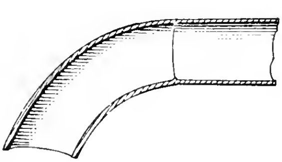
Simple elbow with sharp angle bend. No undercut.



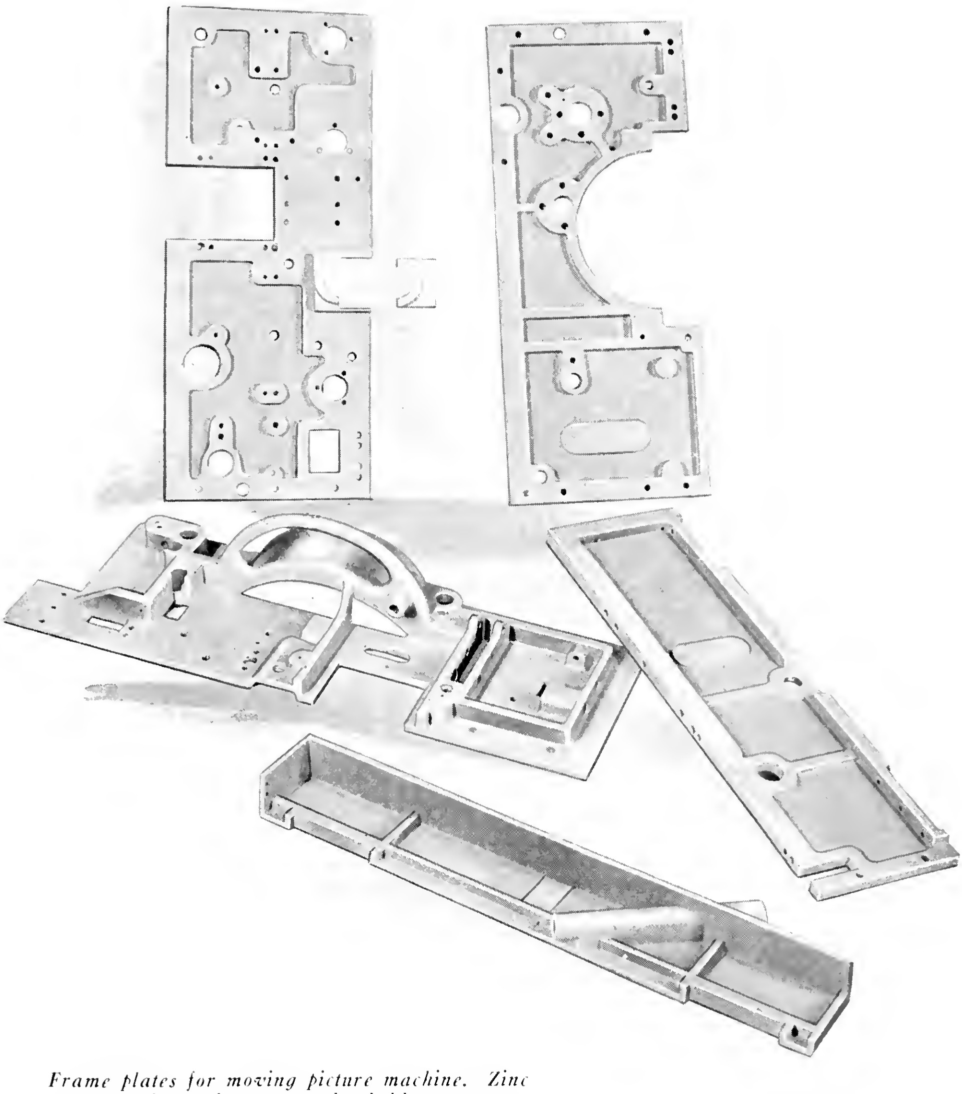
Elbow with rounded bend (undercut). This is formed by a loose piece held on the ends of the cores in the position shown. After the cores are withdrawn this piece is knocked out of the casting.



The undercut section in the middle is formed by a loose core which is knocked out after the core in each end has been withdrawn. This construction requires a substantially increasing taper to permit ejection of the loose core.



Curved core withdrawn on an arc.



Frame plates for moving picture machine. Zinc alloys. These plates must be held to extreme accuracy, as they are used to mount and assemble the mechanism of the machine. They illustrate proper use of fillets and web construction.

Threads

Outside or inside threads may be cast. Outside threads are usually cast by splitting the die lengthwise across the thread or forming it in the same manner on slides. A square thread cannot be cast in this way because it forms an undercut as it approaches the parting line, but it could be cast by inserting a bushing with an inside thread in the die and turning it off the casting. This is slow and troublesome work and should be avoided if possible.

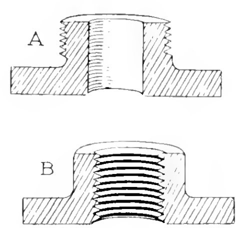
One or two turns of the thread should generally be omitted from the open end of a thread. If the thread extends all the way to the end it results in a feather edge on the part as well as in the die, which will easily break or wear and interfere with the use of the thread.

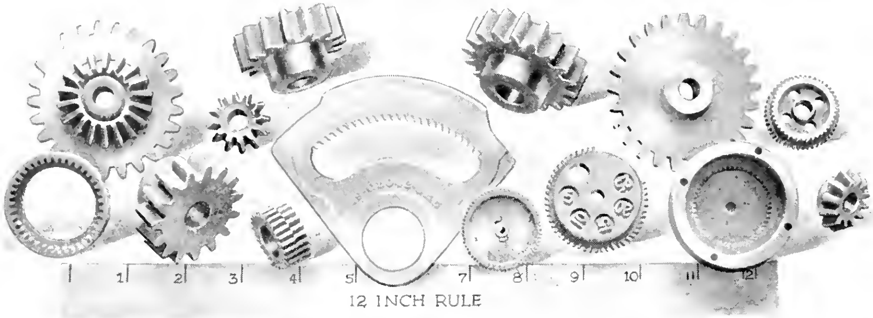
Outside threads commonly have an angle of 29 degrees, 55 degrees, or 60 degrees, and may be held accurate from plus or minus .001″ to plus or minus .003″, according to size.

Inside threads are cast by turning out the threaded core, but small diameters and sometimes the larger sizes may be machined more cheaply, due to the time lost on the casting machine in doing this work. When a number of small holes are to be tapped it is totally impractical to attempt to cast them with the threads and the universal practice is to tap them.

Threads should be made as coarse as possible as they are then less likely to chip in casting and are stronger and more accurate.

In casting parts with pipe connections the better practice is to cast a hole and tap a female thread as shown in illustration B instead of casting a boss with an outside thread as shown in illustration A. The wedging action of a pipe thread exerts a strain which has a tendency to break such bosses, and the design does not permit strengthening without shutting off the opening in the boss. On the other hand as much metal as needed for strength can usually be added around an inside thread which, being larger in diameter than the pipe, is considerably stronger anyway.





Gears

Gears operating at high speeds under loads subjecting them to heavy strain should not be die-cast. It is also not possible to die-cast gears in zinc and aluminum alloys with the same accuracy as they can be machined, and such gears are consequently not as quiet. Spur gears cannot be cast without taper on each tooth towards the parting line of the die. The few examples of die-cast gears made by us shown in the illustration will give an idea of the range of this work.

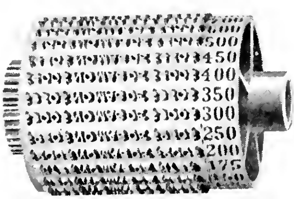
Engraving

Castings may be engraved in any manner desired but certain important considerations must be borne in mind. The cheapest and simplest method is to engrave the die by sinking letters or designs into it. This results in raised engraving on the casting.

If engraving is to be depressed into the casting as though it were directly engraved into it, the work in the die must be raised, which is sometimes an expensive and difficult operation, as it involves cutting away the entire surface around the engraving.

When it is not desired that the letters project beyond the casting the engraving may be raised but on a depressed mat. This is simple, as it merely involves inserting a plug in the die.

When changes of engraving are desired, interchangeable plugs may be made. Engraving may be put on curved or flat surface but it must have plenty of taper



Type-Wheel for Check Protector. Zinc alloy. Letters in right end of part cast depressed to permit filling in with white enamel.

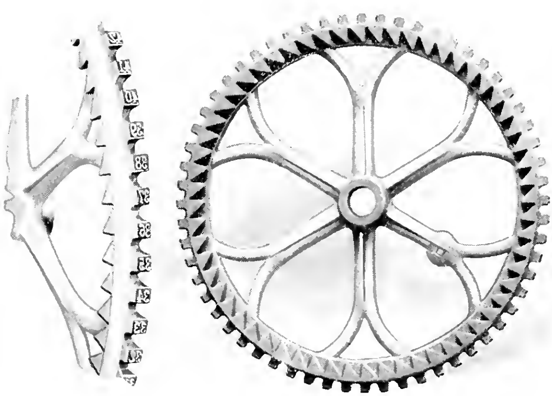
Drill Stands.

to prevent chipping of the edges. For the same reason the engraving must be very carefully done and the letters polished.

If engraving is to be put on any part of a casting which rubs the die in ejecting it forms an undercut and must be made on a slide or a core, which has to be withdrawn before the casting leaves the die.

Clearance for Tools

In machining parts having threads or gears running into a shoulder or flange it is generally necessary to allow for clearance for the cutting tool. In the design of die-castings, however, it is permissible to extend such threads or gears up to the shoulder without any intervening recess or groove, as this construction is not needed in making the die.



Number wheel for time clock. 7" diameter. Tin alloy.

VI. Accuracy

Accuracy in a die-casting depends first of all on the accuracy with which the die is made. The die is virtually a gauge which fixes the size of each part cast from it.

The size and design of a part and the metal used also affect its accuracy. Small castings can be held closer than large ones. Long flat castings warp more. Castings having an odd and complicated design sometimes shrink irregularly. Most of the shrinkage takes place after the castings leave the die.

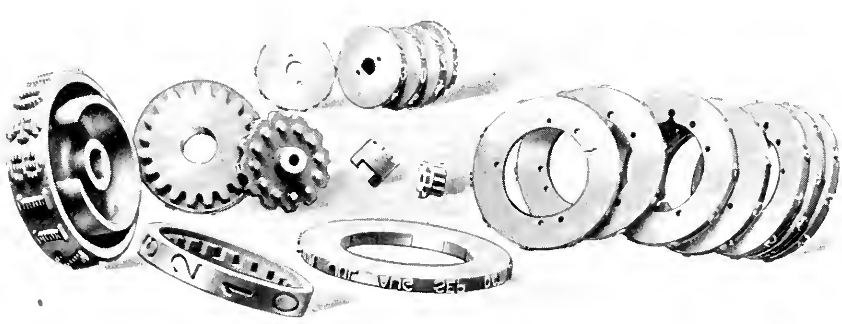
In large castings the die temperature, if permitted to vary materially between operations, as well as the temperatures at which the metal is cast, will affect the accuracy of the part.

Precision die-casting machines are particularly well adapted to meet these difficulties. They are so constructed that proper temperature regulation of dies, machine and metal is easy. The operation of the machine is regular and constant. The position of the dies on the machine, as well as our method of operating and cooling them, all help to keep casting conditions uniform, which in turn affects the flow and finish of the metal as well as the shrinkage.

Accuracy is of course also affected by cleaning operations and removal of gates. This work is therefore given close supervision in our shops.

In specifying dimensions the finished or final sizes should be given and no allowance for shrinkage made, as this must be taken care of by us in the die. For those, however, who desire the information we give the shrinkage of our alloys.

Lead and tin alloys	about .002″ per inch
Zinc alloys	about .004″ per inch
Aluminum alloys	about .007″ per inch



Number wheels.

Exact tables on the accuracy to which die-castings may be held cannot be given as it varies with each part. An idea may be formed from the following table which, however, for some parts may be too close and for others too liberal:

In dimensions of	0-1″	1″ to 2″	2″ to 4″	4″ to 8″	8″ or over
Lead and tin alloys	± .001″	± .0015″	± .002″	± .003″	± .0035″
Zinc alloys	± .0015″	± .002″	± .003″	± .0035″	± .004″
Aluminum alloys	± .002″	± .003″	± .004″	± .005″	± .006″

On particular sizes our engineering department's opinion should be secured and permissible limits agreed upon.

Dimensions across the parting line of dies are more difficult to hold to close limits, because it is almost impossible to keep the die surfaces absolutely clean. We use compressed air under high pressure to clean all particles of dirt and metal from the die surfaces.

The pressure used in casting also has a tendency to force the dies apart. This is more in evidence in large castings made under high pressures and cannot always be entirely prevented.

In most cases, when necessary, we are able to guarantee work as close as ± .002″ to ± .004″ across the parting line, according to the casting.

To a more limited extent there is a certain amount of inaccuracy in those parts of castings which are formed by slides or moving parts in the dies, as dirt or particles of metal sometimes prevent the slides or cores from going completely home. There must also be a certain amount of freedom in such parts to permit easy operation. By close and careful workmanship, great accuracy may nevertheless be maintained.

Holes in which a very close fit is needed, i. e., less than a variation of .001″ should be reamed and stock allowed in the casting for this process. We suggest:

Holes ½″ or less in diameter allow about .004″ for reaming
Holes ½″ to 1″ in diameter allow about .006″ for reaming
Holes 1″ or over in diameter allow about .010″ for reaming

When parts are to be ground, about .005″ should be allowed, and when machining is to be done, about .010″.

All holes or walls from which slides or cores must be horizontally withdrawn or which in ejecting rub die surfaces must be tapered, except in the soft tin and lead alloys. Without taper the die will rub the casting, causing it to chip and crack. When the parts leave the die they are so hot that they are still very frail, and slight pressure will fracture them.

As much taper as possible (from .005″ to .010″ or more per inch) should be allowed as it reduces cost by increasing production and also strengthens the parts.

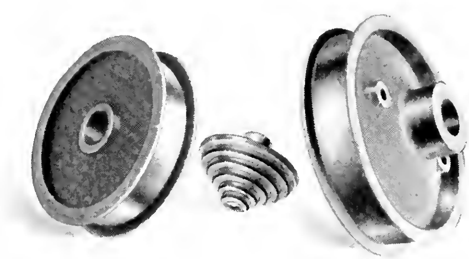
When taper is objectionable the following table will show the smallest amount of draft with which practical results in average cases can be obtained:

Hard tin and lead alloys	.00025″	per inch
Zinc alloys	.0025″	per inch
Aluminum alloys	.003″	per inch

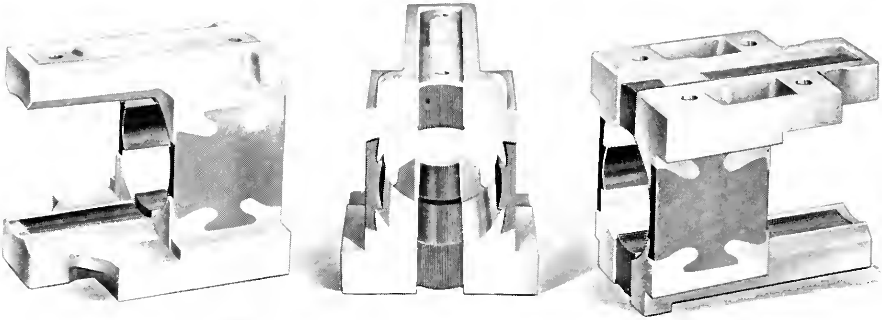
Extreme accuracy in every dimension is expensive because it greatly increases the time necessarily spent on die work. Close or particular sizes should therefore be specified and the accuracy to which they must be held agreed upon. When sizes are specified in fractions instead of decimals it is generally understood that more liberal limits are permissible.

When parts are to fit others not made by us, the best practice is to furnish gauges, to which we will work. In such cases the kind of fit desired should be specified, i. e., whether snug, loose, or tight.

When the dies are first made for parts that must fit others, we always work safely, making the fit loose, and after the first samples are made it becomes a simple matter to determine just how much metal to add to make the fit right. If the fit should be too tight new cores or parts in the die would have to be made, as the change involves adding metal to the die surface.



Pulley wheels, zinc alloys. Five speed pulley in center.



Aluminum magneto housing. Cast iron pole pieces cast in sides and laminated inserts cast in top and bottom.

VII. Inserts

In many cases, when the metal of which a part is to be die-cast is not suitable for certain parts or functions of the die-casting, an insert of some other more suitable metal or material may be placed in the die and the metal cast around it.

Inserts generally increase the cost of castings as the time needed to handle them in the dies delays production. On the other hand they may make otherwise difficult pieces simpler and less troublesome to cast or may replace more expensive metals with cheaper ones, in which case the cost is reduced.

Much also depends on the design of the part and the location of the insert, which may be so inaccessible in the die that it would be cheaper to drive or screw it into the part after it is made.

Subject to rare exceptions, inserts should not be used to strengthen or re-enforce a casting by imbedding them entirely in the metal, as for instance is the practice in concrete construction. The surface of an insert does not adhere to the casting by alloying with the surrounding metal. It merely lays in the metal just as if it were driven in cold. It would fall out if enough of the casting is removed to release its grip on the insert. Consequently the insert really makes the surrounding walls of a given section so much smaller and thinner, so that when strains and stresses are applied to them they are more likely to break or crack and tear away, exposing the insert. If the strains could be taken up by the insert without first passing through the surrounding walls the case might of course be different.

Inserts must be large enough to be handled easily by the machine operator, who wears one and sometimes two gloves on each hand for protection from the heat.

That part of an insert which is imbedded in the casting should be knurled, roughened or so shaped that the metal in shrinking will hold it in place without depending in shrinkage pressure alone.

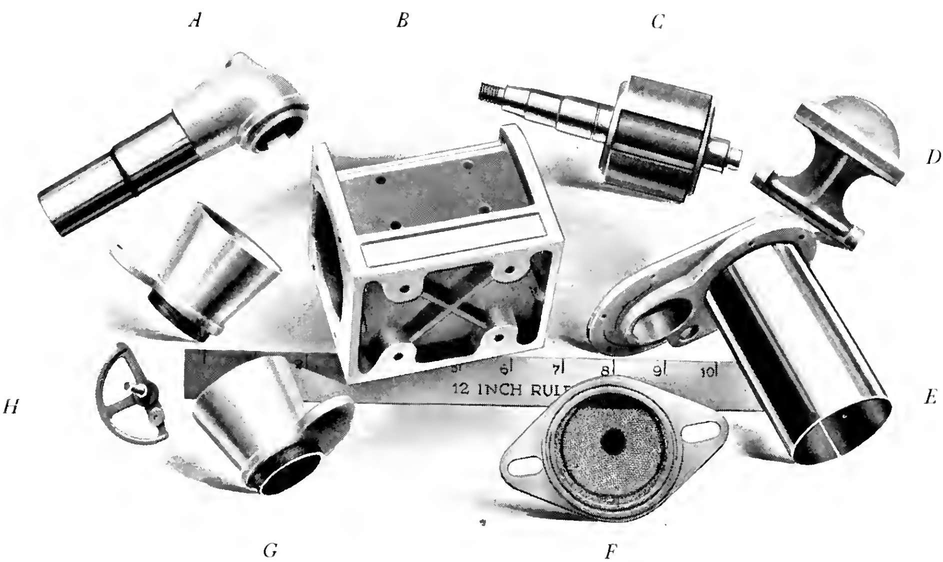
Some part of an insert, sufficient to hold it in the die, must always be exposed; it could not "float" in the die, as then its location could not be controlled.

Inserts should be accurate. Pins or studs fitting into a hole in the dies must fit properly. If they are rough and have burrs they will wear away the die. If they are too large they will not fit. If too small, the die will not grip them properly and the inrushing metal will shift them. Frequently the inserts are so placed that the dies close upon them. In such cases, if they are too large they may seriously injure the die.

It is advisable to avoid the use of inserts so placed that the metal will shrink away from them instead of to them, as for instance an insert forming the outer wall of a casting.

Hardened or tempered inserts may be used without injury except in aluminum die-castings.

Inserts are not furnished by us because it would be impractical to install the wide variety of equipment needed to make the many different kinds of inserts used. They can undoubtedly be bought to better advantage from specialists if not made by the customer.



A Zinc tone arm, brass tube insert.

B Aluminum magneto housing. Iron pole piece cast in.

C Aluminum magneto core. Steel shaft and laminated inserts.

D Check protector lever. Cross hatch, hardened steel perforator inserted.

E Moving picture machine part. Brass insert.

F Gasoline economizer. Copper wire mesh insert.

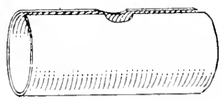
G Aluminum optical instrument parts. Threaded brass tube insert.

H Zinc ratchet, steel shaft.

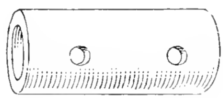
Bearings and Bushings

When a special bearing surface to provide for excessive wear is needed, bronze, steel, or graphite bushings may be cast in.

If thin stock is used it is preferable to cut grooves in the bushings instead of knurling them, as knurling will spread them, causing them to enlarge.



Bushing formed from sheet.



Cast Bushing drilled for anchorage.

Oil holes in inner bushing should be drilled afterwards when possible, because of the difficulty of lining up core pins to fit such holes. The delay in production usually amounts to more than the cost of drilling.

When bushings must line up with other parts in an assembly or must fit perfectly the better practice is to allow .005″ or .010″ for reaming after the castings are made.

A cheap and effective bushing may be formed up out of sheet brass or steel in one or two operations. It should be left with the seam open as shown.

Bushings must be accurate and smooth, to fit the dies and prevent excessive wear.

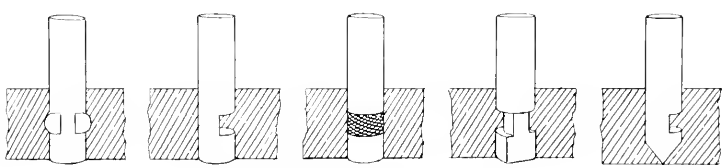
Studs or Pins

A sufficient part of such inserts must always be left exposed (extending from the casting) to permit the die to properly hold it in place. When the design does not permit this it is sometimes necessary to cut off the insert after the casting is made.

The portion of the insert imbedded in the casting, commencing about $\frac{1}{16}''$ or more from the surface of the casting, should be knurled, flattened, grooved or squeezed to provide a better grip.

Provision must always be made in the casting to firmly anchor the insert, having in mind the strength and characteristics of the particular die-cast metal used.

When studs are cast into a wall the opposite side of which is to be polished or finished, a better appearance will be presented if the base of the stud is pointed to prevent its showing through on the surface, as suggested in the illustration below on the extreme right.



Methods of anchoring pins or studs.

Flat Springs

Except in aluminum, springs may be inserted without drawing the temper. Springs are usually anchored by punching holes in them. In some cases eyelets are punched into the holes of the springs to give a better hold.

Springs .003″ to .005″ thick should not be over ¾″ wide as otherwise the metal in shrinking will "pucker" them.

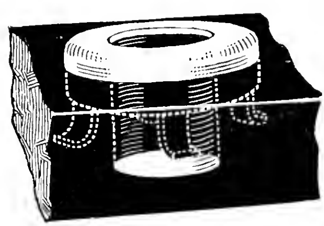
Tubing

Tubing may be used when the design calls for long thin walls which cannot be cast. It is sometimes used for its strength, or to afford a passage for corrosive liquids. It may be bent in any shape and used as an oil passage, following an irregular line through the casting. It is advisable to extend tubing into which cores cannot be fitted beyond the surface of the casting to prevent the tube from being filled with metal. Such tubes must also usually be braced with pins or cores in the die which are withdrawn when the casting is made but leave holes in the casting up to the outside surface of the tube.

Plates and Punchings

When flat plates are inserted and exposed on one face only, it is necessary to hold them in the die with cores or pins running to the face imbedded in the casting. These cores when withdrawn leave holes in the casting. Discs should be countersunk and perforated to permit the metal to grip them.

Sheet meral insert, shown imbedded in section of casting. Frequently used to form bearing for breaker box on magnetos.



VIII. Die-Casting Processes

The origin of modern die-casting practice may be traced to the development of the type-casting machine.' Such machines were built in this country as far back as 1838 and were used for lead and tin alloys only.

The pioneers were Bruce, J. J. Sturgis, W. P. Bair, C. & B. H. Dusenberg and others. In 1885 Mergenthaler brought out his linotype machine and it was the ease and precision with which this machine cast type that suggested the use of a similar principle in casting machine parts out of zinc alloys, which have fusing points ranging only about 200° F. higher than type metals and are much stronger and harder.

It is almost a fundamental principle that accurate castings of high fusing metals cannot be made in commercial quantities without the application of pressure and the use of metal dies. Steel, iron and bronzes have for many years been cast in metal molds by gravity but not accurately and with sharp outlines, and the castings are limited to simple solid pieces.

Clothias Process

The distinction should here be pointed out between the die-casting process and the American application of the French "Clothias" process, in which various non-metallic molding compositions are used. These molds are finer and more substantial than sand and may be used from two to upwards of twenty times, depending on the part cast and the accuracy required. The molds are made from patterns and the metal poured by gravity. Each time the mold is used it becomes less accurate and no moving parts or "permanent" cores may be used. The "Clothias" process, although it has been claimed to produce die-castings by at least one manufacturer using it, is merely a refinement of the sand casting process and does not offer the accuracy or range of the die-casting process.

NOTE.—Illustrations and descriptions of various methods of die-casting are given in Reference Books published by "Machinery" (The Industrial Press, New York City), No. 108 "Die-Casting Machines" and No. 109" Die-Casting Dies, Machines, Methods". See also "Van Wagner Mfg. Co.'s Die-Casting Practice", 1 and 2, published in the January and February, 1913, numbers of "Machinery" and articles there referred to.

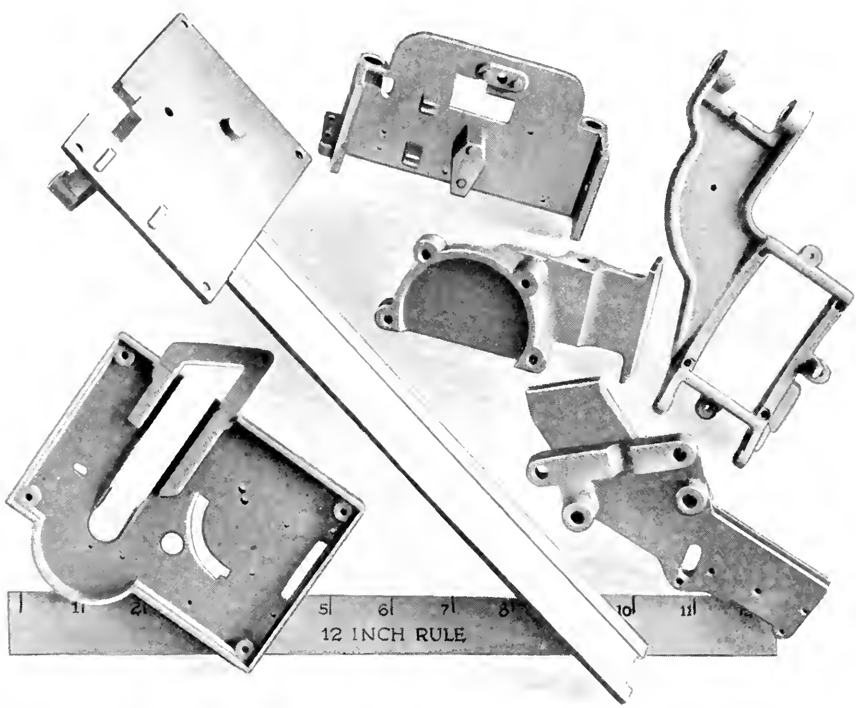
Compression Chamber

All die-casting processes, as the term is generally understood today, employ a compression chamber in some form, in which the metal is subjected to pressure while liquid, and from which it is forced into metallic dies. This chamber may be large enough to hold sufficient metal for only one casting or for a great number.

Various methods of applying pressure have been used. Type casting machines employ a piston traveling in a cylinder and this method has proven satisfactory in casting metals melting at 950° F. or less. Compressed air is widely used and is generally adopted when the fusing point is above 950 degrees, as under such conditions a plunger cannot be operated. In modern dental casting ma-

chines explosive gases are used and in some European processes explosives in the form of cartridges furnish the necessary pressure. Centrifugal force has been employed especially in dental work by spinning the metal chamber and die and then opening a valve, which permits the metal to rush into the mold. This process is slow and can be used only for small parts. It produces very solid castings but is impractical for general commercial application. Iron piston rings are being successfully cast in this manner. In this instance a compression chamber is not used, but the metal is poured into the center of a rapidly revolving die which is made up of steel discs.

Although the plunger construction has proven serviceable it involves many difficulties, especially when zinc alloys are used. If the plunger is fitted close to the cylinder to secure good compression it frequently sticks, due to unequal expansion and warping. Sticking is also caused by dross which becomes wedged between the plunger and cylinder, forming a sandy mass of oxides and metals which alloy with the iron, sometimes practically brazing the plunger to the cylinder. When this occurs the pump must be removed and the plunger drilled or cut out. If on the other hand the plunger is loose, the necessary pressure cannot be obtained. When plungers are well fitted they may sometimes, with care, be operated as long as a month before they become worn too much for use. Plungers cannot be left at rest in a cylinder for any length of time and must always



Parts for vending machines. Zinc and aluminum alloys.

be removed when the machine is not in use, as otherwise they will "stick" or solder to the cylinder, necessitating their being machined out.

Compressed air is objectionable for use with metals that have a tendency to dross excessively, and it is difficult to keep tight joints at the temperatures and pressures needed for die-casting. These objections can be minimized by ingenuity in design, and at temperatures over 950° F. compressed air is thoroughly practical and efficient if properly applied.

The pressure chamber sometimes consists of the entire pot of metal which is covered with an air tight cover and heated with gas or oil fuels, or it may be immersed in an open pot in the form of a pump or a "goose neck" having suitable openings below and above the metal. The pressure chamber is connected directly to the die or die carriage by means of a nozzle. Pressure chambers must be made from metal as no other known substance will carry the required pressures at the casting temperatures of the metals die-cast. Cast iron is almost universally used for this purpose; malleable iron is also used. Steel is attacked more readily by molten metals and has not been as satisfactory.

Die Position

The die may be in any position with relation to the pot. On some machines the pot is raised and the die operated underneath it. This requires the use of a valve to shut off the metal when the die is removed. In other cases the die is on the side of the pot, which also requires a valve to retain the metal in the pot. When the die is placed above the level of the pot no valve is needed, but then the metal must be forced upward into the die, which by some authorities is considered inadvisable. It is no doubt better to let the gravity assist instead of hinder the casting operation, but the use of valves involves so many troubles and objectionable features that working against gravity is by far the lesser of the two evils.

Except for use at comparatively low temperatures no valve has yet been made which will operate satisfactorily in molten metal, due to the wear and the action of the metal in eating away the surfaces of the valve.

Tilting Pots

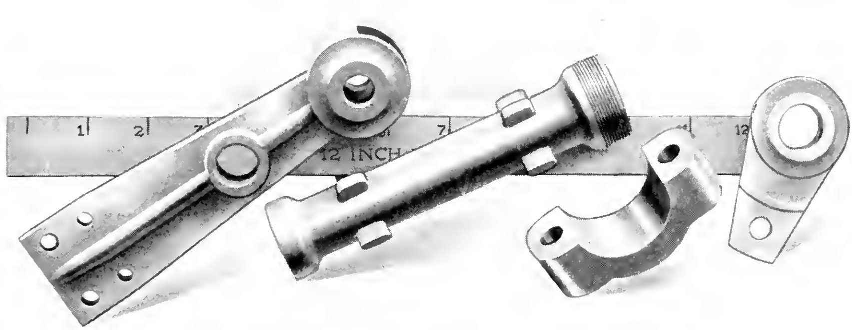
In some machines the metal chamber tilts. Either the entire pot of metal is tilted or a smaller chamber immersed in the pot. In one case the pot is mounted on brackets with the die above it; when a casting is made, pot and die are turned upside down and then the pressure is applied by compressed air in the pot. It is claimed that by this process the metal enters the dies by gravity and that the pressure in the pot is only applied when the die and gate are filled with metal, the pressure merely densifying the casting. The fallacy of this is apparent to anyone who has tried to pour metal into a die by gravity. The metal chills almost instantly and before it has passed out of the gate in many cases. The moment the metal chills it stops the flow and no amount of pressure will fill the mold. To make a die-casting the pressure must be applied to the metal before it enters the die and the finish and accuracy of

the casting will be largely dependent on the speed with which the metal enters the die. If the speed of the inrushing metal permits it to fill the die faster than the die can chill the outer layers of a body of metal of that shape, a good casting can be made; otherwise the casting will show heavy ridges, run marks, etc., and the impression in the die will not completely fill up. The revolving of a large pot and heavy die is slow and the metal in the pot is pretty well shaken up, atomizing and breaking it up, the very thing which is disclaimed for the process. It would seem that a simpler and more direct method of forcing the metal into the dies could be used, with resultant increase in production and less wear and tear on machinery.

Much has been said of the tilting pot or compression chamber, but it is doubtful if it has any advantages. A tilting compression chamber immersed in a pot can easily be filled but it has no other advantage and has the disadvantage of not being rigid. Due to its motion tight air connections cannot be maintained. Air leakage seriously reduces pressures, which of course affects the quality of the castings.

"High Pots"

A machine widely used has the pot containing molten metal above the die and the pressure is applied on the entire pot. This requires the use of a valve, which is a rod passing through the top of the pot into an opening in the bottom. After a little use the valve wears and leaks and then it frequently happens that all the metal runs out of the pot. To avoid this, long bearing surfaces are provided and a certain amount of dependence is placed on the fact that the metal will chill at the gate and act as a plug to prevent further leakage. This plug of chilled metal, however, enters every casting and in some cases prevents the obtaining of best results; as a matter of fact,



Bracket, zinc alloy. — *Auto washing device, aluminum.* — *Bearing cap Liberty Motor, aluminum.* — *R. R. switch signal part, zinc alloy.*

moving a large body of metal suddenly downward much faster than it can be carried by gravity has no advantage over moving a small amount of metal suddenly upward, but on the contrary, the smaller body can be moved upward in a die-casting machine more easily and more rapidly, and in doing so all valves under liquid metal are avoided.

Vacuum Process

In some processes a vacuum is used to exhaust the air from the die cavity just before casting, and it has been asserted that by this means denser castings can be produced. The best results obtained have never justified the claims made for the vacuum processes.

The process of die-casting is such in its very nature that absolutely solid castings cannot be produced by it. All molten metals contain gases which collect in the metal and form "blow holes". These gases, when metals are cast in sand, are allowed to escape through the pores of the sand while the castings slowly cool. No gases can escape through the walls of a metal die and there is no chance for escape anyway, as the castings chill instantly. We overcome these conditions largely by using high grade pure metals and alloys that give off as little gas as possible under closely regulated temperatures.

The metal enters the die at such velocity that it splashes or sprays in some cases, permitting gases to escape into the mold and trapping them and air again almost instantly in chilling. This can be regulated by the size, location or direction of the gate.

In some castings the flow of the metal has a tendency to collect bubbles at certain points. The same result may be noticed when water is forced rapidly around a sharp corner. A bubble will cling to the corner no matter how great the speed of the water. This is caused by the change in direction of force, the heaviest particles of matter being carried the farthest away from the corner and the lightest, being most easily changed in direction, passing nearest the corner. In addition a partial vacuum is formed by the tendency of all the particles of matter to continue in the same direction, and into this vacuum the air and gases are drawn from the water. The same thing is noticed when an object is moved rapidly through water; a vacuum is formed directly behind the moving object, into which a certain amount of air and gases normally present are drawn.

It is the same condition which is frequently responsible for "blow holes" at certain points in die-castings, and it is apparent that the difficulty is not overcome by casting into a partial vacuum. It is possible, however, in most cases to overcome conditions of this kind by changing the size and direction of the gate or its location.

If the die is properly vented and gated, the pressure of the inrushing metal will force out all the air instantly and a vacuum is unnecessary. Even if a little air should stay behind it would not be the cause of porosity in a casting. Castings are made at pressures ranging from about 20 to 70 atmospheres. In other words, if a casting were made in an hermetically sealed die, only about one-twentieth or one-seventieth of the volume of the cavity would be air. Under

ordinary conditions it would be impossible to make a casting in a die from which less than about 95% of the air has escaped. Therefore the ordinary casting made with the usual pressure would only contain one-fourth of 1% to one-fourteenth of 1% of the original air of the die cavity by volume. This would not be sufficient to affect the strength of a casting perceptibly as it would be distributed through the casting.

If the vacuum is not shut off the moment the metal enters the die, in some cases the sucking action of the vacuum has a tendency to draw or suck the metal to the air vents, sealing them and thereby producing a condition much worse than if no vacuum were used. To overcome this, diaphragms have been used to balance the vacuum in the die against a vacuum in the metal chamber, but this only prevents the sucking of the metal into the die before pressure is applied to the compression chamber. The best evidence after all is the result, and in this no vacuum process has shown any improvement in product over the approved and successful processes in which no vacuum is employed. It must also be borne in mind that conditions about a casting machine are such that a high vacuum can not be maintained due to the heat, chips and fins, dust and dirt, etc., constantly present.

Die-castings can no doubt be made in countless ways, and the many processes in use have all produced a commercial product in quantities. But it has been done in most cases at an unnecessarily high cost in time, labor and difficulties encountered, and naturally these factors have had a negative influence on the quality of the product.

Die Carriages

The dies are usually mounted on a carriage on which they are opened and closed. The carriage is usually in the form of two plates to which the dies are bolted and the plates slide on two or four bars. This carriage is attached to the frame of the machine either rigidly or on a hinge in such a manner that the dies may be swung away from the nozzle through which the metal passes, to permit ejection of castings and cleaning of the die and nozzle.

The general practice is to open and close the dies by hand by means of toggles and to hold the die carriage to the nozzle of the machine by means of clamps, which are also operated by hand. The pumping in plunger machines is also generally a hand operation. Hand operated die carriages cannot be made strong and substantial enough except for very light castings to give the best results, due to the weight of large dies and the great pressure of the metal entering the dies. Great strength and endurance is required and it is therefore very difficult to keep high class labor at this work, except at prohibitive wages. Low grade labor cannot be used to produce good work and causes much loss by the production of cracked and defective castings.

The difficulty in applying power to die-casting machine operation has been the varied character of the dies which had to be used and the necessity of holding the dies closed under high pressure. The mechanical action of a press of any character, for instance, would be entirely unsuitable. It has been difficult to

adjust casting pressures and speeds mechanically to the requirements of different dies and it seemed at one time almost impossible to construct a die carriage which could be operated mechanically and which would not involve too much time and trouble to adjust it to any die that might in the usual course be used. Power driven and automatic machines for use in connection with tin and lead alloys and for small and comparatively simple parts such as, for instance, type, counter wheels, and small parts used in connection therewith, have been in use for some time but are not practical for general use with high fusing metals.

Feeding Metal into Dies

There are two methods of feeding the metal into the dies. One between the die surfaces, in which case the nozzle through which the metal enters the dies is at the parting line of the dies; the other through the lower die-block opposite the ejector side, in which case the nozzle through which the metal enters the die is at right angles to the parting line. In the latter case a sprue cutter or gate former is needed.

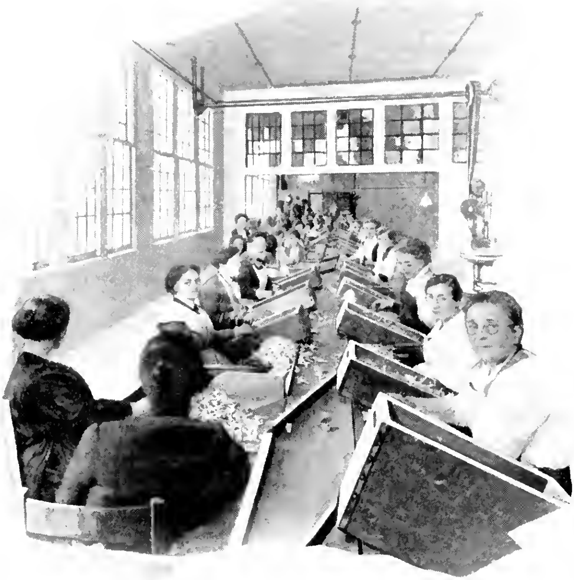
The gate former is usually a tapered bushing attached to a handle which is placed into the die for each operation. It is placed between the die and the nozzle of the casting machine. After the casting is made the gate former is turned usually on a cam so as to lift it out of the die. At the same time it breaks off the sprue or gate to permit ejection through the die block.

The sprue cutter is simply a rod or bar which passes through the die into the opening through which the metal enters the die, called the gate. When the casting is made the sprue cutter is raised free of the gate and the instant the die impression has been filled the sprue cutter is pushed into the gate, closing it and cutting off the flow of metal. This facilitates the removal of the sprue from the die and prevents the metal from running out of the die before it sets should the pressure be released. It also makes it possible to gate through a hole in a casting or into its side without leaving a gate or sprue on the casting as it comes out of the die.

A certain amount of skill and experience are needed to operate sprue cutters, as they must be operated at the instant the die is filled. A fraction of a second early or late may spoil the casting for obvious reasons.

Sprue cutters wear more than cores and are therefore not so accurate when they are used to form any surface of a casting.

Inasmuch as a sprue cutter cuts off the flow of the metal, it cuts off the pressure, and the moment the metal contracts it is no longer under pressure. The beneficial effect of the pressure then is lost on the unsolidified parts of the casting and most important of all, it is not possible to feed in metal to make up for the contraction of the casting. This tends to make the center of a heavy part porous and spongy and also affects its accuracy, as the shrinkage will not be so great when additional metal is fed into the casting under pressure to make up for its contraction in cooling. Lighter parts, however, do not show any appreciable difference when made with or without a sprue cutter.



Moving belt in Trimming Room, Fayetteville plant.

Precision Die-Casting Processes

Precision die-casting machines are the result of scientific analysis of the causes of defective work and an ingenious application of machine power to replace all hand labor in machine operation.

We use both hand operated and power driven machines, as we have found that one type of machines cannot be used with best results for all work. The hand operated machines are used for very light work and their ingenious design makes the labor light and operation fast. Some castings have been made on these machines at the rate of 450 per hour, which means the average operation of the machine seven and one-half times per minute.

The power machines are not automatic in the sense that they may be run without the direction of an operator, but they are in the sense that they automatically perform the various operations required to produce a die-casting by the operation of a control lever. Their advantage over other machines lies not only in the elimination of heavy labor but in the accuracy with which they may be adjusted and controlled, and the greater speed and power they develop. Each die requires different handling to produce the best results. The proper speed and pressure for the metal in entering the dies is easily determined and when once fixed is constantly maintained by simple adjustments on the machine.

Each machine is equipped with a pyrometer which records the metal temperature, which is maintained within a limit of 20 degrees. The proper temperature

of dies is likewise determined and maintained by thermostatic water temperature control. No clamps or toggles are used to operate dies, and the die operating mechanism is very heavy and substantial, remaining rigid and firm under any pressure. This prevents inaccuracy and cracking of castings due to shifting of dies.

We have profited by our own mistakes and have tried to learn as much as possible from the mistakes of others. No known improvement in modern die-casting practice has been overlooked by our engineers. Every detail of our equipment has been developed with a view to the production of castings of uniform quality above all other considerations; cost and speed of production being considered next. In practice we have found by close comparison that in most cases the method which produced the best castings was in the long run also the speediest and lowest in point of cost.

Special presses for removing gates and fins. Trimming Room, Fayetteville Plant.

Carburetor parts. Aluminum and zinc alloys.

IX. Machining Die-Castings

Making allowance for the peculiarities of the particular metals used, die-castings are machined the same as other castings. We have found that speeds, feeds and cutting steels cannot be applied by rule, but it requires judgment and a certain amount of experimenting to determine the best practice in each case.

Only high speed steels should be used for cutting tools. Machine or tool steels do not hold their edge.

For zinc alloys cutting speeds should be from 10% to 20% faster than usual, and for aluminum from 20% to 40% faster; and feeds about 25% slower.

Tools must be kept sharp. This is one of the most important things to keep in mind. Dull tools will tear the metal and forge or spread it. They will cause comparatively thin walls to crack, due to the wedging action of a dull tool.

Taps and reamers should have large flutes to give plenty of room for chips to escape.

Tools should have at least 5 degrees clearance. This amount will avoid chatter, but if fast work is required the clearance should be increased. Soft aluminum die-castings require more than 5 degrees clearance. When an end mill is used better results will be secured if every other tooth is cut back to a sharper angle; that is, for instance, alternating between an angle of 70° and 40°.

Tap holes should be from .003″ to .005″ in diameter larger than for ordinary work, due to the rolling or spreading action of the tap, which will bring the thread up to the right size.

In tapping or reaming parts having thin walls it is best to make fixtures which will grip the castings in such a way that the walls will be supported against the spreading action of the tools.

Zinc metals do not require cutting lubricants although it is sometimes better to use them. For aluminum alloys cutting lubricants should be used. For zinc

alloys any good lubricant that will wash out chips and keep the tool cool will do, such as soda water, soap water, turpentine and kerosene in equal proportions, lard oil, etc. For aluminum we recommend a mixture of one part lard oil to three parts benzine. There are a number of good cutting compounds for aluminum on the market.

In grinding or filing die-castings the wheels or files can be kept from becoming filled or clogged with metal to a certain extent by applying tallow or chalk or both. A file known as the "Vixen" gives better results than ordinary files and grinding wheels are sometimes kept well oiled with ordinary lubricating oil to prevent the pores from filling with metal.

Aluminum "Strut Sockets" for aeroplanes.

X. Electro Plating Die-Castings

Polishing

When a polished surface is required buffing is essential. For very fine work the surface is first polished with about 150 emery, which must be applied with a mixture of parafine and beef suet, prepared with carbolic acid to kill any germs. Dry emery will tear the surface and imbed itself in the castings, so that it will be impossible to secure a proper finish. The surface only should be touched and care should be taken not to go below the "skin" of the casting. The castings are then cut down with Tripoli compound or similar material. After this, color with White Acme Compound. In handling fine work, gloves dipped in whiting should be used.

Long tubular pieces should be polished lengthwise and not crosswise to avoid a wavy surface.

Except for the very finest work, the emery polishing operation may be omitted.

The castings should not be allowed to get so hot that they cannot be held in the hand, as it will cause them to crack and will injure the surface of the castings.

Cleaning

As in all processes, the surface of the castings must be freed from grease, oxides and all foreign substances.

Dirt and polishing material are sometimes first removed with gasoline or benzine.

The castings are then immersed in a hot solution at about 150° F. If necessary the cleaner may contain about one-half pound of caustic soda to the gallon, but should never be so hot or strong that it attacks the metal to any appreciable extent, and the dip should be for a few seconds only. There are several less harmful cleaning solutions on the market containing mild alkalis which may be secured from any well stocked plating supply house. A good cleaner is made up of one pound of soda ash and about one-quarter ounce cyanide of potassium to the gallon of water.

The caustic cleaners re-act with the grease usually present on all castings, forming a soap, which goes into solution. They also re-act with the zinc in zinc base alloys forming zinc oxide and hydrogen. When the metal is placed in the hot bath, the pores open and permit some of the caustic solution to enter. If thereafter the casting is at once plunged into a cold bath, the pores will suddenly close and trap the cleaning solution, which in time, will act on the zinc and generate hydrogen gas. If the casting is plated in this condition the gas in attempting to escape raises the layer of plating, forming blisters which eventually causes the plate to peel off.

It is therefore advisable to wash out all salts before they are trapped in the pores of the metal by immersing in two changes of clean water of the same temperature as the cleaning bath.

Castings which have been corroded by contact with moisture or liquids forming oxide of zinc on the surface may first be cleaned by dipping for a few seconds

in a solution of four parts of water to one of hydrochloric acid, which will dissolve the oxide. This solution should of course be cold and the parts should immediately be washed in water of the same temperature before passing through other cleaning operations and brushed to color. This operation is not used when the castings are first polished, as surface corrosion would be removed sufficiently by that operation.

Another method of cleaning is with what is known as an electric cleaning bath. The solution usually contains various alkalies, as carbonate of soda, cyanide, etc.

A formula strongly recommended is:

Caustic soda	½ lb.
Carbonate of soda	½ lb.
Sodium cyanide	½ lb.
Water	1 gal.

In the electric cleaner nascent hydrogen and sodium are liberated at the cathode. The hydrogen reduces the oxides and the sodium re-acts with the water, forming caustic soda, which saponifies the grease on the cathode surfaces. For zinc castings the temperature of the bath should be about 150° F. and the E. M. F. about 6 volts with a high current density.

After the castings have been washed thoroughly it is sometimes productive of better results to rub them with a paste of Vienna lime, using a soft bristle brush. They should then be thoroughly washed in cold water and they are then ready for the plating bath.

Plating Baths

Next to magnesium and aluminum, zinc is the most electro-positive of the common metals. When metallic zinc is immersed in an acid solution containing metals electro-negative to it, those metals are reduced to their metallic state in the form of fine particles, usually black in color and sometimes in a spongy mass. Nickel, cobalt, tin, copper, gold, and silver, the metals usually plated, are all electro-negative to zinc, and between them and zinc there is in consequence a high difference in potential. This difference is smaller in an alkaline than in an acid bath.

When for instance zinc castings are immersed in a nickel bath, a reaction instantly occurs before the electric current acts, whereby some nickel is deposited on the casting by "immersion" in the form of a black finely divided non-adherent metallic powder. Such deposit when coated with grey nickel, as sometimes happens after a substantial black deposit, causes the plating to become loose and peel.

This black deposit usually shows in the form of streaks at such points on the casting which have not been subjected to the action of the current.

Attempts to overcome this by introducing various salts intended to reduce the potential between the zinc and nickel have not proven satisfactory. Magnesium sulphate has been recommended for the purpose.

The addition of sodium nitrate to the bath is sometimes recommended, although the function of this salt is not to reduce the difference in potential, but to retard the chemical deposition of the black powder on the zinc, which it does to a limited extent.

Another difficulty sometimes arises in plating nickel on zinc, when the parts are irregular in shape, containing hollows or cavities. The current densities in the hollows are smaller than on the more exposed surfaces, giving the nickel a splendid opportunity to deposit by immersion and cause black streaks.

The theory has been advanced that the streaking is due to the decomposition of nickel sulphide in an alkaline bath and the generation of nickel sulphate (black). While this may be true in an alkiline bath, the streaking generally occurs in acid electrolytes, which are the base of most nickel baths.

When streaking cannot be otherwise overcome, it may be avoided by flashing or striking the castings in a nickel or copper bath in which deposition by immersion cannot take place. Such a bath is usually an ordinary plating bath but with a high alkali content (caustic or cyanide) and a small metal content. It is operated at a high voltage, giving the metal very little opportunity to deposit by immersion. Castings are kept in this bath for about 20 seconds. This operation is often performed in connection with an electric cleaning bath, in which case it must be maintained at low temperature, since deposition by immersion takes place rapidly in a hot solution. In this bath the cleaning and plating are simultaneous. It is a very satisfactory method of securing good adherent deposits, but involves the trouble and expense of an extra operation.

In plating zinc as little free cyanide as possible should be used to avoid blistering.

Nickel Bath

In all cases the deposition should be started with an E. M. F. of about 5 or 6 volts and then reduced to about 2½ or 3 volts. In doing this care must be taken that the initial voltage is not maintained long enough to burn the work. For direct nickel plating on zinc die-castings Hammond proposes the use of the following bath:

Single nickel sulphate	34 oz.
Nickel chloride	2 oz.
Boric acid	4 oz.
Sodium citrate	24 oz.
Water	1 gal.

The boric acid is an excellent substitute for the mineral acids on account of its weakness. The sodium citrate retards the deposition by immersion, although it does not alter the difference in potential between the metals. This bath should be kept at room temperature.

For flat articles having no recess or hollows, the following bath will give satisfactory results:

Double nickel salts	6 oz.
Single nickel salts	3 oz.
Nickel chloride	2 oz.
Boric acid	1 oz.
Water	1 gal.

Voltage at start 6 volts and gradually reduce to about 3. Keep the bath slightly acid with boric acid.

Another bath proposed by Hammond for the same purpose is:

Single nickel salts	16 oz.
Nickel chloride	2 oz.
Boric acid	4 oz.
Water	1 gal.

Another formula which will give good results is:

Nickel sulphate	4 oz.
Potassium citrate	2¾ oz.
Ammonium chloride	4 oz.
Water	1 gal.

The usual high voltage at about 5 or 6 to start, reducing at once to about 3. The bath should be kept as nearly neutral as possible to avoid deposition by immersion resulting in black spots or streaks. Caustic potash may be added for this purpose.

All nickel baths should be as near the neutral point as possible, i. e., they should not be strongly acid or alkaline. If the solution becomes too alkaline, boric acid should be added until it becomes slightly acid. If the solution becomes too acid sufficient caustic potash to overcome this should be added. Over acidity will cause black spots or streaks, the result of deposition by immersion.

Brass Bath

Brass is deposited in the same manner as copper, with the addition of zinc salts. The ratio of zinc to copper should not be in the proportions used in making alloys, but rather in the proportion of the chemical equivalents of the two metals, i. e., 63½ parts of copper and 32½ parts of zinc. The color may be deepened or made lighter by reducing or increasing the zinc content.

A good formula is:

Copper cyanide	4 oz.
Zinc cyanide	4 oz.
Soda or potassium	Q. S.
Water	1 gal.
Slight excess above that necessary to dissolve zinc and copper.	

Anodes of rolled brass should be used with an anode surface always in excess of the area to be plated. E. M. F. about 5 volts, best worked in room temperature. There should always be sufficient free cyanide in the bath to keep the anodes clean and free from slime, for which purpose a very small excess is needed, which should be kept as low as possible.

Temperature: Either room temperature or higher.

Another bath recommended is:

Sodium carbonate	4 oz.
Sodium bisulphate	3 oz.
Copper cyanide	2 oz.
Zinc cyanide	2 oz.
Potassium or sodium Q. S. to clean and a slight excess.	
Water	1 gal.

Copper Bath

Castings are seldom copper plated for finish but it is usually done as a base for another deposit or to protect castings from corrosion, which may be done by a copper "strike" or "starting" bath pre-

viously described. For direct copper plating an alkaline bath is best. A good formula is:

Copper cyanide	4 oz.
Sodium or potassium Q. S. with slight excess.	
Water	1 gal.

Potassium or sodium carbonate is usually recommended in such baths but it is unnecessary because some of the excess sodium cyanide, being exposed to the surface, is converted to carbonate. Too much of an excess of sodium cyanide is harmful and it is therefore better to have a small excess and replenish the bath occasionally.

Best results are obtained with cast anodes; they should be cleaned and scrubbed occasionally to remove the slime, which materially weakens the conductivity of the bath. Keep bath at room temperature; E. M. F. 2½ to 3 volts, with initial of about 5.

After the castings have been "struck" in copper, other finishes may be applied according to general plating practice.

Tin Bath

The castings should receive the same treatment for cleaning as for nickel plating. Copper strike for 15 or 20 seconds, which may be done in an electric cleaning bath. Wash in cold water and then place in pyrophosphate bath as follows:

Sodium pyrophosphate	10 oz.
Stannous chloride (fused)	1 oz.
Water	6 gal.

The bath should be maintained at room temperature; E. M. F. about 3½ volts. The tin salts are difficult to dissolve in the pyro-solution and therefore the best method is to enclose them in a muslin bag which should be hung just below the surface and moved to and fro frequently.

Cast tin anodes of the highest quality should be used, but the tin content will not remain constant as the anode dissolves at a lower rate than deposition takes place. Tin should therefore be added periodically by adding solution or hanging a bag of stannous chloride in the bath. An objection which has been made to this bath is its low tin content.

A bath highly recommended by Mather & Cockrum (trans) Electro. Chem. Soc. 29 (1916) is:

Stannous oxalate	5%
Ammonium oxalate	6%
Oxalic acid	1½%
Peptone	¼%
Balance water.	

Reduced to the English system the formula will be:

Stannous oxalate	7 oz.
Ammonium oxalate	8 oz.
Oxalic acid	2 oz.
Peptone	⅓ oz.
Water	1 gal.

This bath is said to give firm, thick and smooth deposits and has the advantage of a higher tin content. Stannous oxalate must nevertheless be added periodically to maintain the tin content of the electrolyte at the proper proportion.

Silver Bath

The casting should be cleaned in the usual way and then flashed in a silver striking bath as follows:

Silver cyanide	½ oz.
Sodium cyanide	8 oz.
Water	1 gal.

The castings should be left in this solution 15 or 20 seconds at a voltage of 5 or 6, after which they may be placed in the silver bath.

A preliminary plating or coating is needed to prevent deposition by immersion, which will cause peeling.

In place of the silver strike a copper or nickel strike may be used but the copper is not advisable when a very thin silver coating is to be given, as the color will show through. The castings are then, after washing, dipped in a mercury bath as follows:

Red oxide of mercury	½ oz.
Potassium or sodium cyanide	8 oz.
Water	3 qts.

The immersion should last about 5 or 6 seconds, in which time a thin film of mercury will be formed which will make the silver adhere better. When it is desired to reduce the expense of plating as much as possible, the striking bath may be omitted and the articles merely quickened in the mercury dip before silver plating. They may be immersed in the silver bath after the dip without rinsing in water.

The silver bath is:

Cyanide of silver	2½ oz.
Sodium cyanide	Q. S.
Water	1 gal.

Q. S. Sufficient to convert the silver nitrate to the double cyanide (solution of the cyanide) and an excess of about one (1) ounce of sodium or potassium cyanide. This excess is needed to convert the silver cyanide which forms at the anode into the double cyanide. If this is not affected, the anode will become surrounded with an insoluble crust of silver cyanide, which increases the resistance to the current.

Sufficient cyanide should be constantly added to keep the anode free from slime and dirt.

Use rolled silver anodes. Initial voltage of about 6, which should be reduced to 2½ to 3. Room temperature.

Gold Bath

The castings should first be well coated with copper or brass and a good lustre maintained on the surface. It would be very wasteful to deposit gold directly on zinc as a good deal of the deposit would be absorbed in the castings. The copper or brass finish furnishes a background for the gold, making it possible to secure good results with a comparatively light deposit.

The ordinary bath is:

Gold cyanide	1 oz.
Water	1 gal.
Sodium or potassium cyanide	Q. S.

Q. S. Sufficient to dissolve the gold cyanide and clear the solution. The cyanide should be kept low, just enough to keep the anodes clear. Too much cyanide will produce a pale, dirty color. Use anodes of fine gold rolled thin to keep the gold content in the bath down. A thin sheet of carbon may also be used. Maintain bath a room temperature, but when desired to keep the gold content down as little as one-third ounce can be used and the temperature kept at 150° F. High temperature is not advisable. If the color becomes yellowish and "brassy" add more gold to the solution by adding gold cyanide dissolved with sodium or potassium cyanide; E. M. F. about 3 volts.

The following formula is also recommended:

Phosphate of soda	8	oz.
Sulphide of soda	1½	oz.
Sodium cyanide	6	pennywt.
Chloride of gold	6	pennywt.
Water	1	gal.

E. M. F. about 2½ volts at about 160 degrees Fahrenheit.

The casting should be protected with the usual "banana oil" lacquers for the silver and gold finishes when possible. The base of these lacquers is usually gun cotton dissolved in amyl acetate. A good coach varnish may also be used, thinned with turpentine or benzine.

Aluminum Polishing

Aluminum will take a very high polish. This is especially true of aluminum-copper alloys, which have a very much harder surface than pure aluminum.

The parts are sometimes first dipped in a dilute solution of caustic potash and then thoroughly rinsed and dried.

The polish should be free from grit and alkali. Nos. 120-150 emery is used applied on a rag or felt wheel with glue. The parts are then buffed with pumice stone and oil or rouge.

The polish will be retained as well as on silver but must of course be kept bright and clean and given the same attention as other metals.

Pickling Aluminum

To remove particles of fat, oxide and other substances a hot 10% solution of cooking soda saturated with common salt is sometimes used and parts dipped for 15 to 20 seconds, then brushed and dipped again for 20 seconds, then washed well in running water and dried. This will give a color resembling matted silver.

Electro-Plating Aluminum

The electro plating of aluminum is attendant with more or less difficulty, due to its being highly electro-positive to all the baser metals (including zinc) except magnesium, and deposition by immersion therefore takes place in the same manner as described with zinc castings. (See p. 70).

Another difficulty is that aluminum becomes coated with a film of oxide instantly on exposure to oxygen, which prevents the deposit from adhering to the surface of the parts.

These difficulties are somewhat eliminated when copper-aluminum alloys are used. Metals containing 8% to 18% of copper, balance aluminum, can be given a good adherent deposit.

The following method of plating aluminum is recommended in the *Brass World* of May, 1907:

Clean the article from grease and dirt in the usual way and then dip in a 5% pickle of hydrofluoric acid, then "quicken" in a mercury bath for a few seconds and again place in the hydrofluoric pickle until it commences to bubble. It is now ready to be copper plated or silver plated before it is nickeled. The copper bath should be about 150° F.

A new method of nickel plating is the subject of a patent described in a French scientific journal. It is claimed the deposit is firm and adherent, practically forming an alloy of aluminum and nickel. It will stand hammering and can (like sheet metals) be bent without cracking the plating, according to the authority.

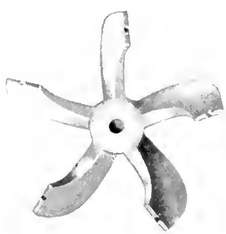
The parts are thoroughly cleaned first in a bath of boiling potash to remove grease and are then scrubbed with milk of lime. This is followed by soaking in a bath of 2% potassium cyanide for several minutes. Next a bath is made of 500 parts of hydrochloric acid, 500 parts water and 1 part iron. The part is kept in this dip until it takes on an appearance of what the inventor calls "metalling watering". After each of these operations the part is carefully washed in water.

The metal is now ready for the nickel bath, proposed as follows:

Water	1 gal.
Nichel chloride	7 oz.
Boric acid	3 oz.

An E. M. F. of 2½ volts is used. The plate takes a high lustre on polishing.

NOTE.—See "Nickel Plating Cast or Sheet Aluminum," *Metal Industry* for January, 1919, page 25.



Aluminum "Vane" for aerial bombs.

XI. Lacquers, Enamels and Chemical Finishes

All metal parts before the application of any finish must be thoroughly cleaned and all foreign matter removed from the surface, to permit the coating to come in direct contact with the metal. The usual methods of cleaning die-castings for electro-plating baths may be followed (see p. 69) or the castings may be washed in hot soapy solutions. Gold-Dust, Oakite or any mild cleanser may be used, after which the parts should be thoroughly rinsed in water of the same temperature as the cleaning bath, then washed in water at room temperature, and then thoroughly dried if enamels, lacquers or paints are to be applied. All finishes which are apt to discolor or corrode or which are easily brushed or worn off should be protected with a good metal lacquer or varnish. A good lacquer commonly used is made by dissolving about 1 oz. of cellulose nitrate in about a quart of amylacitate and thinning the mixture with grain alcohol mixed with ether. Some add fusil oil to the amylacitate.

As a rule lacquers can be bought to better advantage prepared according to requirements from responsible manufacturers.

Cold Lacquers and Enamels

After cleaning, the parts may be sprayed with an air brush or dipped with lacquers and enamels, which need not be baked. Cold enamels usually have a celluloid base. Best results are obtained if a filler is first applied. The filler gives the work a richer tone and also is more adherent, thereby making the enamel stick better. The filler usually takes about half an hour to dry and the enamel, which is generally first thinned down, may be applied. This will dry in about one-half to two hours, according to the material used. Materials for this finish may be secured from several of the larger paint manufacturers and a list of names will gladly be furnished on request.

Baked Enamel

Baked enamel is applied to die-castings in the same manner as to other metals. In all cases except aluminum, the castings must not be heated to more than about 250° degrees F. Enamels which will bake satisfactorily at this temperature may be secured from standard paint concerns.

Metal Finishes

After being cleaned the parts may be coated with aluminum, bronze, or gold lacquers. Metallic powders are used for this purpose, giving any desired finish. The powders are mixed with a suitable carrying liquid, either a good light coach varnish or a metal lacquer.

The coach varnish is preferable for interior work. Before using it should be thinned with turpentine or benzine. For exterior work lacquer is more lasting and will not crack or peel.

Black Finish Antimony Dip

Aluminum, zinc and other alloys may be given a finish similar to gun metal by dipping in the following solution, after being cleansed:

Hydrochloric acid	12%
Antimony chloride	1 to 2%
Water	86 to 87%

The parts should be immersed till well coated with a deep black powder and then thoroughly rinsed in clean water and dried, preferably with hot air. The black powder should then be brushed or very lightly buffed off.

The parts should then be coated with coach varnish or transparent lacquer, as otherwise the finish will come off in time.

Coloring Aluminum

According to a patented process (U. S. patent No. 1023291, issued to S. Axelrod) aluminum may be durably finished in colors ranging from steel grey to brown and finally to black, depending on the temperature at which the work is done. The surface of the aluminum is treated with a solution of cobaltous nitrate maintained either neutral or slightly alkaline. The parts are then heated by muffle or blow pipe. A low temperature will color it steel grey and as the heat is increased the color deepens to brown and finally to black. It is claimed the black will not wear off by friction.

Aluminum may also be coated a brown color of different shades by dipping in ammonium solutions which attack the surface, forming a coating more resistant than the natural metal. This coating, although attacked rapidly by concentrated acid or alkaline solutions, resists corrosion from air and moisture as well as from dilute mineral and organic acids.

Black Oxidizing

A deep black finish may be secured by first copper plating the parts in the usual way and then dipping them in a solution of liver of sulphur. If desired, portions of the parts may then be buffed, exposing the copper background. This finish should be protected with a good coat of lacquer or varnish.

Note.—A very comprehensive article on chemical finishes appears in *American Machinist*, issues of April 27 and May 18, 1911.

XII. Soldering Die-Castings

Zinc Alloys

One of the chief reasons difficulty has sometimes been encountered in soldering zinc die-castings is the formation of a fine coating of aluminum oxide on the die-cast surface. The heat conductivity of zinc is high, causing the solder to chill when applied and thereby preventing it from alloying with the zinc. It is also necessary not to heat the metal over about 275° F.

Any low fusing solder may be used (see Solder Alloys, p. 87). A good solder of almost the same hardness and color of the zinc alloys is composed of:

Cadmium	50%
Tin	30%
Zinc	20%

If cadmium is not desired the following formula may be used:

Zinc	15%
Tin	$84\frac{7}{8}\%$
Aluminum	$\frac{1}{8}\%$

A flux should be used. We suggest a solution of zinc chloride (about 20%) acidified with a few drops of hydrochloric (muriatic) acid, sufficient to keep the salt in solution. The acid if not removed will discolor and corrode the metal around the soldering joint. If this is objectionable, powdered rosin may be used as a "flux" but it is a little more difficult to handle. To overcome this the rosin may be dissolved in alcohol.

The solder should be well rubbed into the casting before it chills to permit it to alloy with the zinc. If possible the parts to be soldered should be rubbed against each other and heated sufficiently to keep the solder liquid while this is done.

The castings after being fluxed are sometimes dipped in molten solder which may be kept in a small pot over a low flame. Care should be taken not to overheat the solder, which causes a volatilization of the metals. If the solder becomes coated with a film of oxide, clean it with a pinch of sal-ammoniac.

After the parts are dipped they are assembled under the heat of a small torch.

If notwithstanding the instructions here given peculiar conditions existing in any particular case cause trouble, it may prove helpful to use a mercuric flux, made up of a saturated solution of mercuric chloride, to which may be added 5 drops hydrochloric acid to every ounce of solution. The mercury acts as a binder making the solder adhere to the part.

Soldering Aluminum

Low temperature solders should not be used as aluminum will not alloy with solders at low heats. Ordinary solders alloy with copper at about 450° F., which is increased to about 650° F. in the case of aluminum.

It is difficult to maintain the proper soldering temperature in working aluminum because it is such an excellent conductor of heat. The aluminum by conveying the heat rapidly away from the point to be soldered reduces the temperature at that point below that needed to properly alloy the solder with the part.

It is frequently said that aluminum is difficult to solder because it has a "greasy" surface. This is a misconception, but the chief trouble is nevertheless to the same effect in principle. Aluminum on being exposed to the air, instantly becomes coated with a fine invisible film of oxide, which prevents the solder from coming in direct contact with the metal. In order to secure a good joint, it is therefore necessary to secure a clean surface by removing this coating.

When metals other than aluminum are to be soldered, it is easy to do this with fluxes or soldering salts, but no satisfactory chemical method of removing the oxide from the surface of aluminum has been found.

No flux should therefore be used except such cleaning fluids as may be needed to clean the surface of dirt and grease. This only applies to the tinning of the aluminum surface, but after it has been tinned the usual fluxes should be used.

Aluminum should be soldered by heating it to about 650° F. and rubbing the solder into the surface of the metal with a stick of solder, or with a blunt instrument or brass wire brush. In this manner the oxide film will be mixed into the solder and the solder permitted to come in direct contact with the part before any air can touch the aluminum surface. The solder must be rubbed in thoroughly and care taken that during the operation it remains perfectly liquid. After the surface is "tinned" it may be soldered to other parts in the usual way.

The best method of applying the heat is by blast lamp or blow pipe. A soldering iron is not as satisfactory. The durability of the joint will depend upon the care and thoroughness with which the solder is "rubbed in".

The chief ingredients in aluminum solders are tin and zinc. Other metals in small proportions are frequently recommended in addition, but their utility has not been demonstrated. Among these are cadmium, bismuth, lead, copper and nickel.

The most widely used and no doubt an excellent formula is that patented in 1892 by Joseph Richards and generally known as Richards' solder. It contains

Phosphor tin	1 part
Tin	29 parts
Zinc	11 parts

This metal is tough and very nearly the color of aluminum. If phosphor tin is not desired or available one part of aluminum may be substituted.

It is not practical to make solder flow into an aluminum joint. The solder must be put where it is wanted by "tinning" the parts first. After being prepared the parts are held together and heated sufficiently to make the solder fluid and then they may be chilled by plunging in water. Care must be taken to permit the joint to set and it should not be moved while the solder is fluid.

A soldered aluminum joint will not hold under water or in moist air and all such joints should be painted, varnished or coated to protect them from corrosion.

As has been previously pointed out, metals corrode and disintegrate rapidly in the presence of moisture when in contact with other metals electro-negative to them. Tin and zinc are electro-negative to aluminum, but no better elements for soldering aluminum have been found.

NOTE.—An instructive article, "Solders for Aluminum," will be found in the *Metal Industry* for November, 1918. Copy of this article can be secured from the Bureau of Standards, Washington, D. C.

Welding Aluminum

The different commercial processes of welding may with skill and experience be applied to aluminum die-castings in many cases. A very interesting article to those wishing more detailed information, by Paul D. Merica, appears in the September, 1918, issue of the *Metal Record and Electroplater,* under the title "Aluminum and Its Light Alloys." The same article is published by the Bureau of Standards, Washington, D. C. (Circulars 76 and 78), and may be had on application.

In general, soldering is preferable to welding except where special strength in the joint is required or where the parts will be exposed to moisture or water and can not be satisfactorily coated or painted. As previously explained, the electro-negative metals in the solders tend to cause disintegration in the joint in the presence of moisture, but as no metals electro-negative to aluminum need be used in welding, welded joints are more lasting under such conditions.

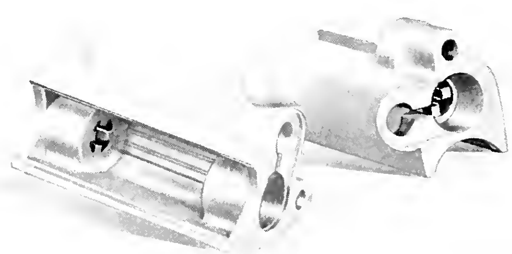
Care must be used in preheating the parts for welding. Too much heat will permanently weaken and warp the metal and cause it to sweat. A good test may be made with sawdust, the danger point being reached when the sawdust begins to char quickly. At the right heat it will char slightly and slowly.

Cements

Metal cements may on occasion be used to advantage instead of the more troublesome and expensive process of soldering. When little or no strain is put on the joint make up a putty of glycerine and lead oxide. When greater strength is required, mix sodium silicate (water glass) with zinc oxide to the consistency of a putty. After application dry for about 24 hours and then heat to about 150° F. for a short while.

A very complete article on plastic cements with formulas may be found in the *Brass World and Platers Guide* for May, 1917.

Fire extinguisher part, Antimonial lead.



TABLES

PRECISION ALLOYS

During a period of over eleven years we have made and thoroughly tried hundreds of white metal alloys and made accurate observation of their qualities when new and after service for extended periods.

The formulas given below have survived a process of elimination which has been thorough and rigid. In strength and service they completely cover the usual requirements of die-cast parts of all kinds. In rare cases very special requirements may justify a modification and in such cases our laboratory will gladly make recommendations that will suit the purpose if it is possible to do so within the limitations of the die-casting process.

Symbol	% Tin	% Copper	% Lead	% Antimony	% Aluminum	DESCRIPTION
AC 10		10			90	Used for mechanical parts of all kinds. Tensile strength between 18,000 and 21,000 lbs. to square inch. Less than half the weight of cast iron. Not harmful to foods. Resistent to corrosion and atmospheric conditions but becomes coated with film of oxide in presence of moisture similar to brass. (We reserve right to vary copper content 5% above or 2% below formula given according to casting requirements of part.)
SN 1	84	7		9		Highest grade genuine babbitt for high speeds and heavy loads.
SN 2	83	5		12		Used for delicate and very accurate parts. Tensile strength comparatively low. Non-corrosive and not harmful to foods. Not affected by atmospheric conditions.
SN 3	82	6	2	10		Highest grade babbitt for high speeds and medium loads.
SN 4	81	4		15		Same as SN 2 but harder.
SN 5	61	3	25	11		An excellent babbitt for use in place of SN 3 at lower cost.
PB 1			87	13		Standard low cost anti-friction metal for light loads and medium speeds. Also used for mechanical parts not requiring strength. Harmful to food. Not corrosive.
PB 2	15		75	10		A good general purpose low cost babbitt. Tougher and stronger than PB-1.
PB 3	10	½	82	7½		Same as PB-2 but slightly lower in cost.
PB 4	5		80	15		A serviceable babbitt similar to Magnolia Metal.
ZN 1	6	3	½	Zinc 90	½	Used for mechanical parts. Tensile strength 12,000 to 16,000 lbs. Weight about same as cast iron. Softer than cast iron. Should be protected from moisture by a coating or plating. Harmful to foods. Soluble in alkalis and mineral acids. Non-magnetic. Should not be subjected to more than 275° F.
ZN 2	14	3	½	82	½	Same as ZN 1 but softer and slightly more expensive. Frequently used for more fragile or difficult parts.

USEFUL INFORMATION

To convert degrees Fahrenheit (F.) into Centigrade (C.) subtract 32, multiply the remainder by 5 and divide by 9. To turn Centigrade into Fahrenheit, multiply the number of degrees by 9, divide by 5 and add 32.

In the Reauner scale used in France 5° C. equal 4° R.

One H. P. expressed in heat units $= \frac{33000}{778} = 42.416$ heat units per minute. A British Thermal Unit (B. T. U.) is the heat required to raise the temperature of 1 lb. of water at or near 39° F. one degree F. One B. T. U. = 778 ft. lbs. One lb. of fuel per H. P. = 1,980,000 ft. lbs. per lb. of fuel or 2,545 heat units per lb of fuel.

Circumference of circle	= diameter × 3.1416
Diameter of circle	= circumference × 0.3183
Area of circle	= square of diameter × 0.7854
Length of arc	= number of degrees × diameter × 0.008727

To find the area of a triangle, multiply the base by one-half the perpendicular height.

To find the area of a trapezoid, add the two parallel sides together and multiply the sum by half the perpendicular distance between them.

To find the area of a regular octagon, multiply the square of the diameter of the inscribed circle by the decimal .828.

To find the area of a regular hexagon, multiply the square of the diameter of the inscribed circle by the decimal .866.

A gallon of water (U. S. Stand.) weighs $8\frac{1}{3}$ lbs. and contains 231 cu. in.

A cu. ft. of water contains 7.48052 U. S. gal., weighs 62.47 lbs. at 32° F.

To find the pressure in lbs. per square inch of a column of water, multiply the height in feet by .434.

Atmospheric air pressure at sea level is 14.7 lbs. per square inch.

Specific gravity = weight of a body compared with the weight of an equal bulk of water.

To find specific gravity. Divide the weight in air by the difference between the weight in air and submerged in water.

GAUGES FOR VARIOUS MATERIALS*

The gauges by which various metals are ordered and sold are not standardized and one metal may be ordered in a variety of gauges. It is safest in ordering to always specify the gauge, but a still better way and one which is gradually gaining ground, is ordering by decimal parts of an inch. The following table gives the gauges which are most usually used for a variety of materials, but, as before stated, the gauge should be specified in ordering.

Material	Gauge	Material	Gauge
Steel Tubing	U. S. S.	Sheet Iron	U. S. S.
Seamless Brass Tubing	Stubs	Sheet Aluminum	B. & S.
Seamless Copper Tubing	Stubs	Sheet Steel	U. S. S.
Steel Wire	U. S. S.	Manganese Bronze Sheets	B. & S.
Brass Wire	Stubs	Brass Sheets	B. & S.
Copper Wire	B. & S.	Copper Sheets[1]	Stubs
Iron Wire	U. S. S.	Steel Rods	U. S. S.
		Tin Plate[2]	

[1] Copper sheets are also gauged by the weight in ounces per square foot and in the heavier sheets in pounds per sheet 30 x 60 inches.

[2] Tin plate is gauged by the weight of a basic box which contains 112 sheets each 14 x 20 inches. This rule holds up to 100 lb. basis. The terms IC, IX, 2X, 3X, etc., are used for the heavier gauges, these terms designating plates weighting a certain number of pounds per basis box.

*Data furnished by U. T. Hungerford Brass & Copper Co., J. M. & L. A. Osborn Co., Carter, Donlevy & Co., and others.

PHYSICAL PROPERTIES OF METALS

	Symbol	Melting Point C.	Melting Point F.	Thermal Con-ductivity AG = 100	Electrical Conductivity HG at 0 = 1	Specific Gravity	Lbs. weight per cubic inch	Lbs. weight per cubic foot	Relative Hardness	Moduli of Elasticity in lbs. per sq. in.	Tensile Strength per sq. inch cast
Aluminum	AL	657	1215	31.33	35.29	2.56	.0924	160.	821	9,000,000	15,000 lbs.
Aluminum bronze {10 AL, 90 CU}		955	1750			7.700	.2779	480.13			60,000 "
Aluminum No. 12 {92 AL, 8 CU}		620	1150			2.82	.1018	176.04			20,000 "
Brass (CU67-ZN 33)		1042	1900			8.32	.3006	519.36		9,000,000	20,000 "
Antimony	SB	630	1166	4.03	2.053	6.71	.2424	418.86			1,000 "
Arsenic	AS	800	1472		2.679	5.67	.2048	353.95			
Bismuth	BL	269	517	1.8	.80	9.80	.3540	611.76			3,200 "
Cadmium	CD	322	610	20.06	13.95	8.60	.3107	536.85	760	7,700,000	
Cobalt	CO	1490	2714		9.685	8.50	.3071	530.61	1450		75,000 "
Calcium	CA	805	1480		12.46	1.57			405		
Copper	CU	1084	1982	73.6	55.86	8.82	.3186	550.59	1360	15,000,000	22,500 "
Chromium	CR	1505	2741			6.80	.2457	429.49			
Gold	AU	1063	1945	53.2	43.84	19.32	.6971	1206.05	979	11,500,000	20,000 "
Glass		872–1260	1600–2300			2.89	.1042	180.			
Iron (white)	FE	1050–1135	1922–2075	11.9	8.341	7.86			1375		
Iron (grey)	FE	1220–1530	2228–2786			7.20	.260	449.20			16,000 "
Lead	PB	327	621	8.5	4.818	11.37	.4108	709.77	570	2,500,000	2,000 "
Magnesium	MG	651	1204	34.3	22.57	1.74			726		
Mercury	HG	—39	—38		1.100	13.59	.4909	848.35			
Manganese	MN	1225	2237			8.00	.2890	499.40	1456		
Molybdenum	MO	2500	4532	1.3		8.60	.3090	534.2			
Nickel	NL	1450	2642		7.374	8.80	.3177	549.1	1410		
Platinum	PT	1755	3191	8.4	8.25	21.50	.7767	1342.13	1107	17,000,000	45,000 "
Potassium	K	62	144		11.23	.87	.0314	54.3	230		
Silver	AG	961	1762	100.	57.22	10.53	.3805	657.33	990	10,000,000	35,000 "
Sodium	NA	97	207	36.5	18.30	.97	.0354	61.1	400		
Steel		1300–1378	2312–2532			7.80	.2834	489.74		30,000,000	50,000 "
Tin	SN	232	450	15.2	8.237	7.29	.2634	455.08	651	4,600,000	4,600 "
Tungsten	W	3000	5432			19.10	.6900	1192.31			
Titanium	TI	1900	3452			4.9	.1915	330.85			
Vanadium	V	1775	3227			5.50	.1987	343.34			
Wrought iron		1500–1600	2732–2912			7.85	.28	483.84		26,000,000	50,000 "
Zinc	ZN	419	786	28.1	16.92	7.15	.2479	428.30	1077		5,500 "

Note.—The melting points of metals vary according to standard authorities, due to a difference in the impurities of the samples tested, slight errors in observation, and inaccuracy of instruments.

Water at 39.1° F. or 4° C. weighs 62.425 lbs. per cubic foot.

Hardness varies with the purity and the manner in which the metals are worked or prepared. The figures on relative hardness were taken from Bottone and are compared to the diamond at 3010. The determination was made by taking the time required to take a cut of definite depth. Bottone found that the results so obtained were proportional to the specific gravity of the metals divided by their atomic weights.

ELECTRO CHEMICAL SERIES

("Weichmann" Notes on Chemistry)

1 Caesium
2 Rubidium
3 Potassium
4 Sodium
5 Lithium
6 Barium
7 Strontium
8 Calcium
9 Magnesium
10 Beryllium
11 Ytterbium
12 Erbium
13 Scandium
14 Aluminum
15 Zirconium
16 Thorium
17 Cerium
18 Didymium
19 Lanthanum
20 Manganese
21 Zinc
22 Iron
23 Nickel
24 Cobalt
25 Thallium
26 Cadmium
27 Lead
28 Germanium
29 Indium
30 Gallium
31 Bismuth
32 Uranium
33 Copper
34 Silver
35 Mercury
36 Palladium
37 Ruthenium
38 Rhodium
39 Platinum
40 Iridium
41 Osmium
42 Gold
43 Hydrogen
44 Tin
45 Silicon
46 Titanium
47 Columbian
48 Tantalum
49 Tellurium
50 Antimony
51 Carbon
52 Boron
53 Tungsten
54 Molybdenu m
55 Vanadium
56 Chromium
57 Arsenic
58 Phosphorus
59 Selenium
60 Iodine
61 Bromine
62 Chlorine
63 Fluorine
64 Nitrogen
65 Sulphur
66 Oxygen

In the above table each element is electro-positive to all the elements which follow it.

METRIC CONVERSION TABLES

NOTE.—Abbreviations: Millimeter, Mm. Centimeter, Cm. Meter, M. Kilometer, Km. Gramme, G. Kilogram, Kilo. or Kg. Metric Ton, M. T. Cubic Centimeter, C. C. Liter, L.

1 Cm. = 10 Mm. 1 M. = 100 Cm. 1 Km. = 1000 M. 1 Kg. = 1000 G.
1 Metric ton = 1000 Kg. 1 L. = 1000 C. C.

A liter of water weighs a kilo and contains a cubic decimeter in volume.

A U. S. gallon contains 231 cubic inches and weighs 8.345 lbs. of water at 62° F. The English gallon correspondingly weighs 10.017 lbs. and contains 277.27 cubic inches. An English gallon contains 4.54346 L. and is the equivalent of 1.20032 U. S. gallons.

The following table gives only the denominations in practical and general use:

1 mm.	= .03937 in.	1 in.	= 25.4 mm.
1 cm.	= .3937 in.		= 2.54 cm.
1 sq. cm.	= .1550 sq. in.	1 sq. in.	= 6.452 sq. cm.
1 cub. cm.	= .0610 cub. in.	1 cub. in.	= 16.39 cub. cm.
1 m.	= 39.37 in.	1 ft.	= .3048 m.
1 sq. m.	= 10.76 sq. ft.	1 sq. ft.	= .0929 sq. m.
1 cub. m.	= 35.31 cub. ft.	1 cub. ft.	= .0283 cub. m.
1 km.	= .62137 miles	1 mile	= 1.6093 km.
1 hectare	= 2.471 acres	1 acre	= .4047 hectares
1 L.	= 1 cub. decim.	1 quart (liquid)	= .9463 l.
	= .2642 U. S. gal.	1 gal. U. S.	= 3.785 l.
	= 61.023 cub. in.	1 fl. oz.	= .02967 l.
	= .03531 cub. ft.	1 quart (dry)	= 1.101 l.
	= 2.202 lbs. water	1 bush.	= 35.24 l.
	= 33.84 fl. oz.	1 oz. av'd.)	= 28.35 g.
1 g.	= 15.432 grains	1 oz. (Troy)	= 31.10 g.
	= .03527 oz.	1 lb.	= .4536 kg.
1 kg.	= 2.2046 lbs.	1 ton (2240 lbs.)	= 1.016 m. t.
1 m. t.	= 1.102 tons (2000 lbs.)	1 ton (2000 lbs.)	= .9072 m. t.
	= .9842 tons (2240 lbs.)		

A FEW LOW FUSING ALLOYS AND SOLDERS

	% Lead	% Tin	% Bismuth	% Cadmium	Melting °C	Point °F
No. 1	96	4			292	558
No. 2	90	10			283	541
No. 3	83	17			266	511
No. 4	75	25			250	482
No. 5	67	33			227	441
No. 6	50	50			188	370
No. 7	40	60			168	334
No. 8	33	67			171	340
No. 9	33	34	33		140	284
No. 10	10	40	50		116	240
Isaac Newton's alloy	30	20	50		100	212
Rose's alloy	28	22	50		95	203
Wod's alloy	25	13	50	12	60	140
Lipowitz alloy	27	13	50	10	66	150
D'Arcet's alloy	25	25	50		93	200
Expanding alloy	67		8	25	66	150

NON-FERROUS METAL TUBING TOLERANCES

Tubing can be furnished in copper, and the commercial alloys of copper and zinc, such as high brass, bronze, phosphor bronze, and tobin bronze.

Composition.—As specified ot meet the requirements of use.

Temper.—As specified in the order; may be hard, half hard or annealed. If annealed, the tubing may be soft, or light annealed.

Size variation.—On inside and outside diameter and the thickness of the walls, as follows:

Outside and Inside Dimensions

Up to ½ in. inclusive	0.002 in. over or under
Over ½ in. to and including ¾ in.	0.0025 in. over or under
Over ¾ in. to and including 1 in.	0.003 in. over or under
Over 1 in. to and including 1¼ in.	0.0035 in. over or under
Over 1¼ in. to and including 1½ in.	0.004 in. over or under
Over 1½ in. to and including 1¾ in.	0.0045 in. over or under
Over 1¾ in. to and including 2 in.	0.005 in. over or under
Over 2 in.	¼ of 1 per cent. over or under

No combination of variations on the same tube shall make the thickness of the wall vary from the nominal by more than the following amounts:

Thickness of Wall

Up to and including 1/64 in.	0.001 in. over or under
Over 1/64 in. to and including 1/32 in.	0.002 in. over or under
Over 1/32 in. to and including 1/16 in.	0.003 in. over or under
Over 1/16 in. to and including ⅛ in.	0.005 in. over or under
Over ⅛ in. to and including ¼ in.	0.008 in. over or under
Over ¼ in. to and including 5/16 in.	0.0125 in. over or under
Over 5/16 in. to and including ⅜ in.	0.015 in. over or under

Special limits.—On all stock where the above commercial variations are not permissible limits shall be specified in the order.

CO-EFFICIENTS OF FRICTION

The relative value of different materials of construction ascertained as the result of tests made by the National Brake & Clutch Company is tabulated as follows:

Materials		Co-efficient
Metal and cork Leather and cork Fibre and cork	on dry metal	0.35
Metal and cork Leather and cork Fibre and cork	on oily metal	0.32
Fibre on dry metal		0.27
Fibre on oily metal		0.10
Leather on dry metal		0.23
Leather on oily metal		0.15
Charred leather on oily metal		0.08
Metal on dry metal		0.15
Metai on oily metal		0.07

The co-efficient will vary with the condition of the contacting surfaces. Smooth and unyielding surfaces offer less resistance than rough and yielding ones. In metal to metal contacts different metals are usually employed for the opposing surfaces, as bronze and steel in plate clutches and cast iron and steel in brakes of the shoe type.

WEIGHTS AND MEASURES

TROY WEIGHT

20 grains = 1 pwt.
20 pwts. = 1 ounce
12 ounces = 1 pound.

APOTHECARIES WEIGHT

20 grains = 1 scruple.
3 scruples = 1 dram.
8 drams = 1 ounce.
12 ounces = 1 pound.

The ounce and the pound in this are the same as in troy weight.

AVOIRDUPOIS WEIGHT

$27\frac{11}{32}$ grains = 1 dram.
16 drams = 1 ounce.
16 ounces = 1 pound.
25 pounds = 1 quarter.
4 quarters = 1 cwt.
2,000 lbs. = 1 short ton.

DRY MEASURE

2 pints = 1 quart.
8 quarts = 1 peck.
4 pecks = 1 bushel.
36 bushels = chaldron.

LIQUID MEASURE

4 gills = 1 pint.
2 pints = 1 quart.
4 quarts = 1 gallon.
$31\frac{1}{2}$ gallons = 1 barrel.
2 barrels = 1 hogshead.

TIME MEASURE

60 seconds = 1 minute.
60 minutes = 1 hour.
24 hours = 1 day.
7 days = 1 week.
28, 29, 30 or 31 days = 1 calendar month (30 days = month in computing interest).
365 days = 1 year.
366 days = 1 leap year.

CIRCULAR MEASURE

60 seconds = 1 minute.
60 minutes = 1 degree.
30 degrees = 1 sign.
90 degrees = 1 quadrant.
4 quadrants = 12 signs, or 360 degrees = 1 circle.

SURVEYOR'S MEASURE

7.92 inches = 1 link.
25 links = 1 rod.
4 rods = 1 chain.
10 sq. chains or 160 sq. rods = 1 acre.
640 acres = 1 square mile.
36 sq. miles (6 miles square) = 1 township.

LONG MEASURE

12 inches = 1 foot.
3 feet = 1 yard.
$5\frac{1}{2}$ yards = 1 rod.
40 rods = 1 furlong.
8 furlongs = 1 sta. mile.
3 miles = 1 league.

SQUARE MEASURE

144 sq. inches = 1 sq. ft.
9 sq. ft. = 1 sq. yd.
$30\frac{1}{4}$ sq. yds. = 1 sq. rod.
40 sq. rods = 1 rood.
4 roods = 1 acre.
640 acres = 1 square mile.

CUBIC MEASURE

1,728 cubic in. = 1 cu. ft.
27 cubic ft. = 1 cubic yd.
128 cu. ft. = 1 cord (wood)
40 cu. ft. = 1 ton (shpg).
2,150.42 cu. in. = 1 standard bushel.
231 cu. in. = 1 standard gallon.
1 cu. ft. = about .8 of a bushel.

DRILL SIZES FOR STANDARD THREADS

Tap holes for die-castings should be .003″ to .005″ larger than the sizes given, due *Aluminum and zinc alloys.*

These sizes give an allowance above the bottom of thread on sizes 1/4 to 2; varying respectively as follows: for V" Threads, .010″ to .055″; for U. S. S. and Whitworth threads, .005″ to .027″.

These are found by adding to the size at bottom of thread 1/4 of the pitch for "V" threads, and 1/8 of the pitch for U. S. S. and Whitworth, the pitch being equal to 1″ ÷ No. of threads per inch.

In practice it is better to use a larger drill if the exact size called for cannot be had.

Size Screw	No. of Threads	Size of Drill			Size Screw	No. of Threads	Size of Drill		
		U. S. S.	"V"	W.			U. S. S.	"V"	W.
1/4	24	.201	.196	.202	15/16	9	.808	.790	.810
1/4	20	.191	.184	.192	1	8	.854	8.32	.856
5/16	18	.248	.239	.249	1 1/16	8	.917	.894	.919
3/8	16	.302	.293	.303	1 1/8	7	.957	.932	.950
7/16	14	.354	.345	.355	1 1/4	7	1.082	1.057	1.085
1/2	13	.409	.399	.410	1 3/8	6	1.179	1.144	1.182
1/2	12	.402	.391	.403	1 1/2	6	1.304	1.269	1.307
9/16	12	.465	.453	.466	1 5/8	5 1/2	1.412	1.373	1.416
5/8	11	.518	.506	.520	1 5/8	5	1.390	1.347	1.394
11/16	11	.581	.568	.583	1 3/4	5	1.515	1.473	1.519
3/4	10	.632	.618	.634	1 7/8	5	1.640	1.597	1.644
13/16	10	.695	.680	.697	1 7/8	4 1/2	1.614	1.566	1.619
7/8	9	.745	.728	.747	2	4 1/2	1.739	1.691	1.744

DRILL SIZES FOR S. A. E. THREADS

Size of Tap	Size of Drill
1/4 inch x 28 threads	7/32 inch
5/16 " x 24 "	17/64 "
3/8 " x 24 "	21/64 "
7/16 " x 20 "	3/8 "
1/2 " x 20 "	7/16 "
9/16 " x 18 "	1/2 "
5/8 " x 18 "	9/16 "
11/16 " x 16 "	39/64 "
3/4 " x 16 "	43/64 "
7/8 " x 14 "	25/32 "
1 " x 14 "	29/32 "
1 1/8 " x 12 "	1 1/64 "
1 1/4 " x 12 "	1 9/64 "
1 3/8 " x 12 "	1 17/64 "
1 1/2 " x 12 "	1 25/64 "

The above tap drills allow a thread within 1/64 inch of full thread.

WIRE GAUGES
Sizes in decimal parts of an inch

No. of Wire Gauge	American or Brown and Sharpe	Birmingham or Stubs' Iron Wire	Pounds per ft. 1 in. wide B. W. G.	Washburn and Moen	Pounds per 100 ft. round W. & M. G.	Polish'd drill or Stubs' Iron Wire	No. of Wire Gauge
0000	.46	.454	1.512	.3938	40.94		0000
000	.40964	.425	1.412	.3625	34.73		000
00	.3648	.38	1.265	.3310	29.04		00
0	.32486	.34	1.132	.3065	27.66		0
1	.2893	.3	1.000	.2830	21.23	.227	1
2	.25763	.284	.946	.2625	18.34	.219	2
3	.22942	.259	.863	.2437	15.78	.212	3
4	.20431	.238	.793	.2253	13.39	.207	4
5	.18194	.22	.733	.2070	11.35	.204	5
6	.16202	.203	.676	.1920	9.73	.201	6
7	.14428	.18	.600	.1770	8.03	.199	7
8	.12849	.165	.550	.1620	6.96	.197	8
9	.11443	.148	.493	.1483	5.08	.194	9
10	.10189	.134	.446	.1350	4.83	.191	10
11	.090742	.12	.400	.1205	3.82	.188	11
12	.080808	.109	.363	.1055	2.92	.185	12
13	.071961	.095	.316	.0915	2.24	.182	13
14	.064084	.083	.276	.0800	1.69	.180	14
15	.057068	.072	.240	.0720	1.37	.178	15
16	.05082	.065	.217	.0625	1.05	.175	16
17	.045257	.058	.193	.0540	.77	.172	17
18	.040303	.049	.165	.0475	.58	.168	18
19	.03589	.042	.140	.0410	.45	.164	19
20	.031961	.035	.117	.0348	.32	.161	20
21	.028462	.032	.107	.03175	.27	.157	21
22	.025347	.028	.093	.0286	.21	.155	22
23	.022571	.025	.083	.0258	.175	.153	23
24	.0201	.022	.073	.0230	.140	.151	24
25	.0179	.02	.067	.0204	.116	.148	25
26	.01594	.018	.060	.0181	.093	.146	26
27	.014195	.016	.053	.0173	.083	.143	27
28	.012641	.014	.047	.0162	.074	.139	28
29	.011257	.013	.044	.0150	.061	.134	29
30	.010025	.012	.040	.0140	.054	.127	30
31	.008928	.01	.0333	.0132	.050	.120	31
32	.00795	.009	.0300	.0128	.046	.115	32
33	.00708	.008	.0266	.0118	.037	.112	33
34	.006304	.007	.0233	.0104	.030	.110	34
35	.005614	.005	.0167	.0095	.025	.108	35
36	.005	.004	.0133	.0090	.025	.108	36
37	.004453	......	....	....	......	.103	37
38	.003965	......	....	....	......	.101	38
39	.003531	......	....	....	......	.099	39
40	.003144	......	....	....	......	.092	40

SHRINKAGE TABLE

For use in casting the metals mentioned. Figures are based on walls about .25″ thick. Thicker walls will shrink somewhat more and thinner walls less.

Pure aluminum	.203″	per foot
No. 12 aluminum alloy	.156″	" "
Cast iron	.125″	" "
Iron, cast or malleable	.125″	" "
Steel	.250″	" "
Brass	.1875″	" "
Zinc	.3215″	" "
Lead	.3125″	" "
Copper	.1875″	" "

SIZES OF NUMBERS OF THE UNITED STATES STANDARD GAUGE FOR SHEET AND PLATE IRON AND STEEL

An Act Establishing a Standard Gauge for Sheet and Plate Iron and Steel

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled: That for the purpose of securing uniformity the following is established as the only gauge for sheet and plate iron and steel in the United States of America namely:

Number of Gauge	Approximate Thickness in Fractions of an Inch	Approximate Thickness in Decimal Parts of an Inch	Weight per Square Foot in Ounces Avoirdupois	Weight per Square Foot in Pounds Avoirdupois
0000000	1/2	.5	320	20.00
000000	15/32	.46875	300	18.75
00000	7/16	.4375	280	17.50
0000	13/32	.40625	260	16.25
000	3/8	.375	240	15.00
00	11/32	.34375	220	13.75
0	5/16	.3125	200	12.50
1	9/32	.28125	180	11.25
2	17/64	.265625	170	10.625
3	1/4	.25	160	10.00
4	15/64	.234375	150	9.375
5	7/32	.21875	140	8.75
6	13/64	.203125	130	8.125
7	3/16	.1875	120	7.5
8	11/64	.171875	110	6.875
9	5/32	.15625	100	6.25
10	9/64	.140625	90	5.625
11	1/8	.125	80	5.00
12	7/64	.109375	70	4.375
13	3/32	.09375	60	3.75
14	5/64	.078125	50	3.125
15	9/128	.0703125	45	2.81253
16	1/16	.0625	40	2.5
17	9/160	.05625	36	2.25
18	1/20	.05	32	2.
19	7/160	.04375	28	1.75
20	3/80	.0375	24	1.50
21	11/320	.034375	22	1.375
22	1/32	.03125	20	1.25
23	9/320	.028125	18	1.25
24	1/40	.025	16	1.
25	7/320	.021875	14	.875
26	3/160	.01875	12	.75
27	11/640	.0171875	11	.6875
28	1/64	.015625	10	.625
29	9/640	.0140625	9	.5625
30	1/80	.0125	8	.5
31	7/640	.0109375	7	.4375
32	13/1280	.01015625	6 1/2	.40625
33	3/320	.009375	6	.375
34	11/1280	.00859375	5 1/2	.34375
35	5/640	.0078125	5	.3125
36	9/1280	.00703125	4 1/2	.28125
37	17/2560	.006640625	4 1/4	.265625
38	1/160	.00625	4	.25

And on and after July first, eighteen hundred and ninety-three, the same and no other shall be used in determining duties and taxes levied by the United States of America on sheet and plate iron and steel. But this act shall not be construed to increase duties upon any articles which may be imported.

Sec. 3. That in the practical use and application of the standard gauge hereby established a variation of two and one-half per cent. either way may be allowed.

Approved March 3, 1893.

LIST OF NINE DIFFERENT STANDARD GAUGES USED IN THE UNITED STATES

DECIMAL EQUIVALENTS (Inches)

No. of Gauge	Amer. or Brown & Sharpe Iron Wire	Birmingham or Stubbs Iron Wire	Washburn & Moen Iron Wire	Imperial Wire Gauge	U.S. Std. for Plate (Iron and Steel)	Stubbs Steel Wire	Twist Drill and Steel Wire	Washburn & Moen Music Wire	Wood and Machine Screws	No. of Gauge	Fractional Parts of an Inch	Decimal Equiv. of Sixty-fourths, etc.
8-0	....	....	....	....	....	....	This gauge from one to three thousandths larger than same Nos. of Stubbs steel wire gauge	.0083	....	8-0	1/64	.01563
7-0	....	....	....	....	.500	....		.0087	....	7-0	1/32	.03125
6-0	....	....	....	.464	.469	....		.0095	....	6-0	1/16	.625
5-0	....	....	....	.432	.438	....		.010	....	5-0	5/64	.07813
4-0	.460	.454	.394	.400	.406	....		.011	....	4-0	3/32	.09735
3-0	.410	.425	.363	.372	.375	....		.012	.032	3-0	7/64	.10938
2-0	.365	.380	.331	.348	3.44	....		.013	.045	2-0	1/8	.125
0	.325	.340	.307	.334	.313	....		.014	.058	0	9/64	.14063
1	.289	.300	.283	.300	.281	.277	.228	.016	.071	1	5/32	.15625
2	.258	2.84	.263	.276	.266	.219	.221	.017	.084	2	11/64	.17188
3	.229	.259	.244	.252	.250	.212	.213	.018	.097	3	3/16	.1875
4	.204	.238	.225	.232	.234	.207	.209	.019	.110	4	13/64	.20313
5	.182	.220	.207	.212	.219	.204	.206	.020	.124	5	7/32	.21875
6	.162	.203	.192	.192	.203	.201	.204	.022	.137	6	15/64	.23138
7	.144	.180	.177	.176	.188	.199	.201	.023	.150	7	1/4	.25
8	.128	.165	.162	.160	.172	.197	.199	.024	.163	8	17/64	.26563
9	.114	.148	.148	.144	.156	.194	.196	.026	.176	9	9/32	.28125
10	.102	.134	.135	.128	.141	.191	.194	.027	.189	10	19/64	.29688
11	.091	.120	.121	.116	.125	.188	.141	.072	.426	28	37/64	.57813
12	.081	.109	.106	.104	.109	.185	.189	.030	.216	12	21/64	.32813
13	.072	.095	.092	.092	.094	.182	.191	.028	.203	11	5/16	.3125
14	.064	.083	.080	.080	.078	.180	.185	.031	.229	13	11/32	.34375
15	.057	.072	.072	.072	.070	.178	.182	.033	.212	14	23/64	.35938
16	.051	.065	.063	.064	.063	.175	.180	.035	.255	15	3/8	.375
17	.045	.058	.054	.056	.056	.172	.177	.036	.268	16	25/64	.39063
18	.040	.049	.048	.048	.050	.168	.173	.038	.282	17	13/32	.40625
19	.036	.042	.041	.040	.044	.164	.170	.040	.295	18	27/64	.12188
20	.032	.035	.035	.036	.038	.161	.166	.011	.308	19	7/16	.4375
21	.028	.032	.032	.032	.034	.157	.161	.043	.321	20	29/64	.45313
22	.025	.028	.029	.028	.031	.155	.159	.046	.334	21	15/32	.46875
23	.023	.025	.026	.024	.028	.153	.157	.048	.347	22	31/64	.18438
24	.020	.022	.023	.022	.025	.151	.151	.051	.360	23	1/2	.5
25	.018	.020	.020	.020	.022	.148	.152	.055	.374	24	33/64	.51563
26	.016	.018	.018	.018	.019	.146	.150	.059	.387	25	17/32	.53125
27	.0141	.016	.0173	.0164	.0171	.143	.117	.063	.400	26	35/64	.54688
28	.0126	.014	.0162	.0149	.0156	.139	.141	.066	.413	27	9/16	.5625
29	.0112	.013	.015	.0136	.014	.134	.136	.076	.439	29	19/32	.59375
30	.010	.012	0.11	.0124	.0125	.127	.129	.080	.453	30	39/64	.60938
31	.0089	.010	.0132	.0116	.0109	.120	.120	....	.466	31	5/8	.625
32	.0079	.009	.0128	.0108	.0101	.115	.116	....	.479	32	41/64	.64063
33	.007	.008	.0118	.010	.0093	.112	.113	....	.492	33	21/32	.65625
34	.0063	.007	.0104	.0092	.0085	.110	.111	....	.505	34	43/64	.67188
35	.0056	.005	.0095	.0084	.0078	.108	.110	....	.518	35	11/16	.6875
36	.005	.004	.009	.0076	.007	.106	.1065	....	.532	36	45/64	.70313
37	.0044	....	....	.0068	.0066	.103	.104	....	.545	37	23/32	.71875
38	.0039	....	....	.006	.0062	.101	.1015	....	.558	38	47/64	.73438
39	.0035	....	....	.0052	....	.099	.0995	....	.571	39	3/4	.75
40	.0031	....	....	.0048	....	.097	.098	....	.584	40	49/64	.76563
41	....	....	....	....	....	.095	.096	....	.597	41	25/32	.78125
42	....	....	....	....	....	.092	.094	....	.611	42	51/64	.79688
43	....	....	....	....	....	.088	.089	....	.624	43	13/16	.8125
44	....	....	....	....	....	.085	.086	....	.637	44	53/64	.82813
45	....	....	....	....	....	.081	.082	....	.650	15	27/32	.84375
46	....	....	....	....	....	.079	.081	....	.663	46	55/64	.85938
47	....	....	....	....	....	.077	.079	....	.676	47	7/8	.875
48	....	....	....	....	....	.075	.076	....	.690	48	57/64	.89063
49	....	....	....	....	....	.072	.073	....	.703	19	29/32	.90625
50	....	....	....	....	....	.069	.070	....	.716	50	59/64	.92188

LETTER SIZES STUBBS STEEL WIRE

A	.234	I	.272	R	.339
B	.238	J	.277	S	.348
C	.242	K	.281	T	.358
D	.246	L	.290	U	.368
E	.250	M	.295	V	.377
F	.257	N	.302	W	.386
G	.261	O	.316	X	.397
H	.266	P	.323	Y	.404
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